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GENERAL INFORMATION

The "*International Journal of Biometeorology*" (Intern J. Biometeor.) is published by the "*International Society of Biometeorology*".

The Journal covers the following subjects:

1) Critical reviews and surveys of world literature of high standard in special fields and problems of Biometeorology.
2) Short papers on original research which is of international interest.
3) Summaries of completed biometeorological studies which have been published in full by the author(s) in any other scientific periodical.
4) Short reports on research in progress in order to stimulate team work between research workers in different parts of the world.
5) Abstracts of important articles and book reviews.
6) Summaries of activities, symposia and congresses of national and international organizations dealing with biometeorological subjects.
7) Reports from the Chairmen of the special scientific committees of the Society.
8) Information on dates and programs of symposia and congresses related to biometeorological subjects.
9) Advertisements of scientific firms of good standing.

Editorial Correspondence: Manuscripts and all correspondence should be addressed to the Editor-in-chief:

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Manuscripts: Two copies of the complete text of each article and abstract should be submitted. Manuscripts should be prepared according to the "Instructions to Contributors" (back page).

The editors reserve the right to refuse any manuscript submitted, whether on invitation or otherwise, and to make suggestions and modifications before publication.

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Preface
by
the Editor

As editor of the new Journal I should like to express my sincere thanks to the Executive Board, particularly to Dr. Sargent and Dr. Tromp, for their support and encouragement in the task of developing the new Journal in accordance with the suggestions of the members of the Society and the requirements of the science of biometeorology.

A new Editorial Board has been nominated, and I wish to thank its members who are expert scientists in the different fields of biometeorology,for their willingness to devote their time and experience to the Journal. In addition,a Publication Committee consisting of three members has been established to consider general policy.All the responsibilities connected with printing and mailing the Journal and with subscription and advertising are still carried by Dr. Tromp as Managing Editor,who has gathered a great deal of experience in previous years.

Not only a new editorial staff is introduced with this issue but the Journal itself appears in a new guise. I am grateful to my sister-in-law Miss Madeleine Dinkel, who is a professional book designer in London, for suggesting the design for the cover.

The "Directions to Contributors" have been newly revised.More detailed directions than are given on the inside of the back page of the cover are now in preparation and will be supplied on demand in the near future in each of the three languages. Arrangements are also being made to prepare a list of abbreviations of the titles of those scientific periodicals which are related to the Journal.

Although no abstracts of papers published elsewhere are printed in this issue, special attention will be given to this matter in the future.These abstracts will be written only in English. To enable specific plans to be made for the establishment of an up-to-date abstract service in the Journal, the members are referred to the questionnaire enclosed. In this questionnaire every member is asked to state,first,whether he is willing to send abstracts of his own scientific papers which are published elsewhere and are within the scope of the Journal, and second, whether he is willing to prepare abstracts of papers written by other authors and published elsewhere.

Many unforeseen questions arose with the revision of the Journal in the preparation of this issue. In this situation the editors had to decide whether to wait until all these questions were settled or to go ahead on the strength of what has been achieved up till now. As the Journal has not been published for some time it was felt that the publication of this issue could not de delayed any longer.

The Journal is an organ of information and its growth and significance depends greatly on the response and the contributions to it. The first issue of the new Journal is herewith presented to the reader who is invited to play a part in its future development.

Introduction

Among the stated purposes of this Society is the synthesis and critical evaluation of the facts which constitute the science of biometeorology. The Executive Board has urged the membership for a number of years that this purpose should really be the number one purpose. This viewpoint of the Board was unanimously endorsed at the Second Congress held in London in September, 1960. Then it was voted that the character of the Society's publication should be radically changed. It was voted that the JOURNAL should contain review articles prepared by scholarly authorities and classified lists of references to current papers in the various areas of biometeorology. This step was a wise one, for the community of biometeorologists has long expressed the view that the most urgent need in our rapidly developing science is a careful evaluation and interpretation of just where we stand with regard to clearly established fundamental principles concerning, first, the factors of the physical environment which are biologically effective, and, second, the mechanisms whereby living organisms respond and adjust to their physical environment. Therefore, it is with great pleasure that the Board can announce in this first issue of the revised JOURNAL that we are seriously ready to undertake this important and difficult task.

The Executive Board is most encouraged by the considered opinions of a group of scientists which met in Boston, Massachusetts, U.S.A., in June 1961, to consider the future development in atmospheric sciences in general and biometeorology in particular.
The strong feeling of this group, insofar as biometeorology was concerned, was that the first task facing biometeorological societies was the preparation of critical reviews of the literature which collectively and thoroughly defined the state of the art and the depth of support in fact for our theories and hypotheses. The second task for biometeorology was to foster the graduate training of students.

Recently the Executive Board recommended to the membership of the Society that the name of our organization be shortened. The Board recommended that the name of the Society become "The International Society of Biometeorology", and that the name of the new JOURNAL be "THE INTERNATIONAL JOURNAL OF BIOMETEOROLOGY". This proposal has been endorsed by an overwhelming majority of the members. This renaming of the area was also urged by the group of biometeorologists which met in Boston to discuss the future of the atmospheric sciences. The position is very simple: Meteorology is the parent science and climatology is strictly a branch of meteorology. Meteorology deals with the daily weather changes, the weather changes that living organisms experience. Climatology deals with average weather conditions and the frequencies of extremes of weather. Since these averages are rarely if ever experienced by living organisms, we are really studying the effects of the weather and not of the climate. Therefore, it is more accurate to call our area biometeorology than bioclimatology. Originally we adopted the latter term because we wanted to give recognition to Professor Dorno who first suggested "bioclimatology" as the name of this general area of research. The use of the term has led to considerable confusion; therefore the Board has proposed the more accurate designation.

To undertake the leadership of this new JOURNAL requires the support of a vigorous and imaginative scholar and a strong and active Editorial Board. The Executive Board has discussed at some length with several highly qualified scholars the great place which the new JOURNAL might play in the future growth and development of biometeorology. We are pleased to announce at this time that Dr. Wolf H. Weihe has accepted the responsibility for developing the JOURNAL along the lines which we all think are important. Dr. Weihe was born in September, 1923, in Herford-Westfalia, Germany. He studied medicine from 1942 to 1948 and was awarded the degree of Doctor of Medicine in 1948 from the University of Munich. During three years of this period he was in the German Naval Medical Corps. Between 1948 and 1953 he undertook special studies in internal medicine at the Medizinische Poliklinik, University of Munich, and then in 1953 - 1954 trained in biochemistry at the

French-German Université de la Sarre, Homburg/Saar.During the past seven years he has had a broad and varied experience in research in environmental physiology. In 1954 - 1955 he worked at the High Alpine Research Station, Jungfraujoch, and Department of Biochemistry and Physiology, University of Bern, Switzerland.In 1956 he was a research assistant physiologist at the G.W. Hooper Foundation Medical Center,University of California,San Francisco.

Since 1960 he has been research physiologist at the High Alpine Research Station,Jungfraujoch, International Foundation,in charge of climatic physiology. This Foundation and his research is supported by the Max Planck Gesellschaft e.V. Germany. Professor Dr.A.v. Muralt is the President of the Foundation High Alpine Research Station at Jungfraujoch and Director of the Institute of Physiology, University of Bern.

The special areas of science in which Dr. Weihe has done research are serum proteins, function of parathyroid glands, sperm metabolism,endocrinology of reproduction,liver metabolism, pathophysiology of plague infection and effect of plague endotoxin, and effect of high altitude on men and laboratory animals.

Dr. Weihe thus brings to the JOURNAL a very broad training in the medical and biological sciences and a wide experience with the particular problems of an interdisciplinary science such as biometeorology. The Board wants him to know that they stand strongly behind him in the work that he is about to undertake and give him every encouragement for a productive and successful execution of his plans to develop the Journal along the lines so urgently required by the community of biometeorologists.

Frederick Sargent, II, M.D.
President

Heat Tolerance in Cattle - its Concept, Measurement and Dependence on Modifying Factors

by

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INTRODUCTION

Heat tolerance may be defined as the ability of the body to endure the impact of a hot environment without suffering ill-effects.

In this general form the definition probably satisfies most of the people interested in heat tolerance. However, different people will give different interpretations to the term "ill-effects". To the animal husbandry man it may mean a poor performance with respect to grazing, thrift and milk yield, to the veterinary practitioner a low fertility and proneness to disease, and to the physiologist a displacement from the normal of body functions such as body temperature and respiratory activity. As a consequence, various people will judge heat tolerance by a number of different criteria; they speak, with regard to heat tolerance, "different languages", which makes any comparison difficult.

Yet, physiologically there are no completely isolated reactions to heat because of the relationships existing between the various body processes. Whether or not certain body functions, such as milk secretion, are economically exploited by man, does not make any difference. Heat tolerance is essentially an entity which is merely looked at and approached from different angles by people differing from each other with respect to interest, training and facilities.

It would appear therefore physiologically reasonable and, from the standpoint of general applicability, desirable to find a way of assessing an animal's innate overall capacity to cope successfully with a hot environment. Any attempt in this direction is faced with difficulties both fundamental and practical.

Three main factors have to be considered: the hot climate (the stress producing agent), the animal body (the target) and a suitable scale for expressing numerically the effect of the hot climate on the animal body.

The aim of this paper is to discuss various aspects of heat tolerance in cattle by attempting to answer the following questions:

(1) Which of the many climatic factors have to be taken into consideration for a heat tolerance test?
(2) At what intensity should they be applied?
(3) What is the relation of some selected body structures to heat tolerance?
(4) Which body functions are eligible for use as criteria in a heat tolerance test?
(5) Which are at present the best ways of expressing the impact of a hot climate on the body?
(6) Which factors influence heat tolerance in a given animal, and how strong are these influences?

C L I M A T E

GENERAL

A heat tolerance test, in order to give reproducible and comparable results, must be carried out in a standard thermal environment. This is difficult to achieve in the field where one has to accept the atmospheric conditions prevailing at the moment.

It is true that animals tested simultaneously in the same geographical area may readily be ranked according to their heat tolerance which in turn allows selection of those animals (of one or of many different breeds) which stand up best to a given local climate. But, since the atmospheric conditions vary in a given area with time, and in a given time with area, results so obtained represent only relative values, i.e., they are not comparable to results obtained elsewhere or at another time. Extrapolation to a standard climate by using correction factors, may be possible, but can hardly be considered satisfactory. The controlled atmosphere of a hot room is generally preferable, although this also has its limitations.

In choosing the atmospheric conditions for a heat tolerance test, it has to be decided what climatic factors should be considered and at what intensities they should be used.

QUALITATIVE ASPECTS

The principal component factors of a thermal environment are temperature, humidity, wind and solar radiation. Ideally they should all be included in a heat tolerance test either in combination or singly one after the other. Each climatic factor affects the body in a different way thereby making demands on specific structures and mechanisms of the body. A high environmental temperature, provided it does not exceed body temperature, interferes with the dissipation of body heat by convection and radiation, which emphasises the importance of factors such as the ratio of body surface to body mass, the circulation of the blood and the vascularization of the skin. A high air humidity interferes with dissipation of body heat by evaporation. It thus plays a role in evaluating an animal's capacity for evaporative cooling by sweating and panting. In a non-sweating non-panting animal, air humidity would be of minor importance as a climatic factor. Wind promotes dissipation of body heat by convection (provided air temperature does not exceed the body temperature); it also assists evaporation. Therefore, the larger the (relative) surface area of an animal and the higher its rate of skin evaporation, the more it would benefit from the cooling power of wind.

Solar radiation, in contrast to the other three climatic variables, imposes a heat load on the body by transferring energy to it from outside. The presence of solar radiation in a heat tolerance test allows a determination to be made of an animal's capacity for absorbing solar radiation, which is largely dependent on the characteristics of its skin and hair coat. The superiority in heat tolerance of an animal having a glossy, light coloured, i.e., a highly reflecting coat, over an animal having a dull, dark coat, can only be evaluated in the presence of solar radiation or a suitable artificially produced substitute.

Since all these climatic factors can affect the animal's thermal balance, it would appear desirable to express them jointly as a single figure, so that different climates, in spite of differences in their component factors, would be mutually comparable. Various attempts have been made to combine two or more climatic factors into a single index. A well known index of this kind is the "cooling power" which is a measure of the amount of heat lost by a specified body under given conditions of temperature, wind velocity and radiation. Since such an inert body cannot make adaptatory adjustments, its response to climatic stress will, of course, not reflect quantitatively the response of a living body; it will, however, express in a single figure the thermal demands made by the combined action of several climatic factors on the temperature regulating mechanisms of the animal body. In this respect combined climatic indices may serve a useful purpose.

In heat tolerance studies, however, it may be important to know the isolated effect of single climatic factors. Indeed, heat tolerance may be limited by a "climatic master factor", such as solar radiation in the desert and air humidity (at an elevated level of air temperature) in the jungle, emphasising the importance of coat character in the one instance and of evaporative cooling in the other instance. Thus, for different types of "hot" climates selection of heat tolerant animals may have to concentrate on different and specific animal characters. For this reason one might conceive several different heat tolerance tests, each giving specific information on the effect of one dominating climatic factor. In this way one could think of a dry heat tolerance test, a humid heat tolerance test and a radiant heat tolerance test.

There is also the possibility of using non-climatic factors as stress producing agents in a heat tolerance test. Heat generated in the body by physical exercise and drug-induced fever are two such possibilities. In heat tolerance tests with man it is common practice for the subject to perform work in a warm atmosphere. Consequently these subjects are exposed to the combination of two stressors which are largely additive in their demands on the thermoregulatory capacity of the body. Such combined tests might be of use also in cattle, since a hot environment and the necessity to walk long distances (in search of water and food) are often linked with each other in the tropics. A heat/exercise test for cattle, although of a special type, has been devised by Dowling (1956). Such tests, while giving most valuable information may be difficult in their interpretation. A good score in the test might be due to a high efficiency in eliminating heat from the body, or alternatively, to a high efficiency in producing physical work with a minimum caloric cost. Moreover, such tests usually require extra facilities and labour; they therefore should be made the subject of a special investigation rather than the basis of a standard procedure of a general heat tolerance test.

Even stronger reservations must be made regarding the use of drugs for raising body temperature in a heat tolerance test, because in fever, in contrast to hyperthermia, the setting of the central "thermostat" of the body is changed to a higher level so that thermoregulatory reactions work in relation to this new setting.

QUANTITATIVE ASPECTS

The effect of a hot environment on the body depends not only on the nature of the climatic factors involved, but also on their intensity. If the temperature of the environment equals that of the animal and, at the same time, the air is completely saturated with water vapour, the animal cannot lose any heat to the environment. Changes in body temperature, measured under such conditions, reflect the accumulation of body heat which cannot be dissipated.

In order to obtain information on the efficiency of the various channels of heat loss, gradients in temperature and humidity between an animal and its surroundings must be established by lowering the environmental temperature, the air humidity or both. If the air humidity is lowered, heat loss becomes possible, but only through evaporation. A dry atmosphere at body temperature has the advantage that the number of possible explanations for any physiological changes observed in the animal is reduced. It is obvious that a heat tolerance test, intended to give information on the efficiency of sweating, has to be conducted in a relatively dry atmosphere, in order to allow the sweat secreted to have a cooling effect.

Considering the overall intensity of a climate, not in terms of physical units, but in terms of animal response, 4 degrees of severity, namely, mild heat, moderate heat, severe heat and excessive heat may be arbitrarily differentiated and described as follows:

(1) MILD HEAT: The thermoregulatory mechanisms of the body can cope completely with the heat load, so that body temperature remains normal.
(2) MODERATE HEAT: The thermoregulatory mechanisms work at a highter intensity; body temperature can be stabilised but at an elevated level.

(3) SEVERE HEAT: The functional reserves of the thermoregulatory mechanisms are becoming exhausted; body temperature rises continually.

(4) EXCESSIVE HEAT: The thermoregulatory mechanisms are grossly overtaxed;the animal succumbs within a short time. A differentiation between severe heat and excessive heat may be difficult in some instances.

On which of these degrees of thermal intensity should a heat tolerance test be based? The use of mild heat might be advocated, because mild heat activates the heat loss mechanisms without causing a displacement of body temperature. To measure these early and subtle changes in the temperature regulating mechanisms might appear more satisfactory than to measure their activity at a level where they are already accompanied by signs of heat distress. Yet, under field conditions, significant changes in body temperature do occur, if only of a transient nature. An extrapolation from the effects of mild heat to those of moderate or severe heat may not be permissible, Indeed, such an extrapolation would appear as equally problematic as selecting a team of prospective Mount Everest climbers on the basis of tests carried out on lowland hills.

Moderate heat would best simulate conditions prevailing in sub-tropical and tropical regions at least over certain periods.It would also leave the animal in a state of thermal equilibrium which facilitates the measurement of various body functions.

With regard to severe heat, it is true, of course, as has been pointed out by Ladell (1957), that any climate in which thermal equilibrium cannot be attained or established, is, strictly speaking, intolerable. But, severe heat will always be tolerated for a limited period. This happens for instance during the diurnal cycle of a tropical day, when the heat load becomes maximal for a few hours around mid-day. It would not therefore be unrealistic to test an animal's heat tolerance under the impact of severe heat. Heat tolerance may then be expressed in terms of tolerance time,by measuring the time for which a standard hot environment can be endured before the body reaches an arbitrarily chosen level of temperature.

Excessive heat has been used in several species of laboratory animals in order to determine lethal temperatures.The knowledge of the highest body temperature and the maximal environmental heat load just compatible with life would be of interest because it would furnish a ceiling value of heat tolerance. If the lethal body temperature of cattle were to be found to be a consistent figure, it could be made the upper limit of a heat tolerance scale. In judging an animal's heat tolerance,one might then state for instance:the animal's body temperature has approached its lethal value by x degrees,rather than state that its body temperature has risen y degrees above normal.It might well bepossible that the lethal body temperature is less variable than what is accepted as normal body temperature so that it would be a more reliable base of reference.It also seems logical to express a physiological response as a fraction of its maximal response,thus getting an indication of the margin still in hand.Whatever useful information might be drawn for a heat tolerance test from the knowledge of an animal's lethal body temperature,this value could be established only in a limited number of animals. Excessive heat, therefore, cannot be applied in routine heat tolerance tests.

From these considerations it would appear that the choice for a suitable thermal environment for a heat tolerance test would be between moderate heat and severe heat. Both conditions are realistic, in that they may occur naturally.

Since, with rising intensity of the external heat load,the duration of a heat exposure may (in some cases must) be shortened,heat tolerance tests carried out in severe heat are of short duration,which is convenient in routine testing of large numbers of animals. In these conditions individual differences in heat tolerance will also show up best which will facilitate the subsequent selection of animals.

It is appreciated, of course, that what is mild heat to one animal may be moderate heat to another animal. These categories simply relate to the response of the average animal with extreme animals varying upwards or downwards.The interest with regard to animal selection lies with the heat tolerant individuals, i.e. with those whose response to heat is below average.

BODY STRUCTURES

Various structural features of the animal body, such as the surface/mass ratio and the texture and colour of the hair coat, must, from a consideration of physical laws, be expected to have a bearing on the body's thermal balance. A large relative body surface, in particular large body appendages (dewlap, navel fold, ears, tail), a short glossy coat and a well pigmented, movable skin are generally considered as characters associated with a high heat tolerance.

To what extent this represents a direct causal relationship is not yet sufficiently known. McDowell, Lee & Fohrman (1953) did not find significant differences in the surface/mass ratio between European and Zebu cattle, which otherwise differed in heat tolerance. McDowell (1958) found that surgical removal of hump and dewlap in Red Sindhi bulls did not depress their heat tolerance, as judged by rectal temperature and respiratory rate, although it would appear that the test atmosphere employed (40.5°C) would not exclude the possibility that such appendices at lower air temperatures could be useful devices for losing heat by radiation and convection.

A clear relationship has been established between coat texture and heat tolerance (Bonsma, 1949). Animals with a sleek coat withstand heat better than animals with a woolly coat. Similarly, a high proportion of medullated hair fibres in the coat favours heat tolerance (Dowling, 1959a). Recently Turner & Schleger (1960) have described a subjective method for scoring of cattle coats which seems to afford a good prediction of cattle performance in a hot climate.

The establishment of such correlations may be of great practical value for several reasons. Many of these body structures can be determined very easily, some of them even without instrumental measurements (see: felting test, p. 15). They also tend to have a high degree of heritability which facilitates their genetic fixation by breeding. Structural features which have clearly been shown to be correlated to physiological responses indicative of an animal's heat tolerance, possess prognostic value. The knowledge of these features may enable a breeder to predict the future heat tolerance of a young animal. Moreover, this can be done, without subjecting the animal to heat, i.e., in a temperate climate.

It should be realised, however, that any such structure is not eligible as a criterion in a heat tolerance test proper, because it does not change measurably during exposure to an acute standard heat stress.

BODY FUNCTIONS

A hot environment affects the entire animal. This means that a great number of physiological activities undergo specific changes. The information derived from a heat tolerance test should thus be expected to become more complete the larger the number of activities observed.

However, the use of a large number of criteria in a heat tolerance test, has the disadvantage of complicating the performance of a test. Also in view of using the result of a heat tolerance test for animal selection, a large number of criteria may be undesirable since selection becomes progressively more difficult and less effective, the larger the number of animal characters that are taken into account.

It is necessary, therefore, to make an optimal choice among the various body functions. Although there are interrelationships between the various physiological activities of the body, suggesting that the behaviour of any one of them might be representative of all the others, some of these activities will be better suited than others, to serve as criteria in a heat tolerance test. There are also some special points which have to be borne in mind, as may become clear from the following considerations:

(1) Many body functions are related to and therefore indicative of either heat production or heat loss of the body. Yet, heat tolerance is the resultant of both these processes. Although a heat tolerance test is not a procedure meant to measure an animal's thermal balance - this is the object of calorimetry - it is not entirely satisfactory to judge heat tolerance only in terms of either a heat loss mechanism or in terms of a character pertaining to heat production.
(2) The interpretation of isolated heat responses of the animal may be made difficult by two or more of them behaving in a compensatory fashion with each other. Man cools by sweating, but normally not by panting; the dog, in contrast, cools by panting but not by sweating. Cattle make use of both these avenues of cooling in variable proportions. Some cattle, notably European breeds, are poor sweaters. This inadequacy is to some extent compensated for by increased respiratory activity. Other cattle, notably tropical breeds, are better sweaters, which enables them to have less recourse to respiratory cooling, at least as long as the heat stress is moderate. If it becomes severe, even the good sweater will increase its respiratory activity and eventually bring it to the same level as that of the poor sweater. The good sweater, however, has the advantage of possessing a functional reserve of respiratory cooling which may be gradually mobilised as the environment becomes hotter. This point, incidentally, again stresses the importance of carefully choosing the degree of severity of heat to be used in a heat tolerance test. Compensatory changes between various avenues of thermal flow during acclimatization of man to dry heat have been described by Eichna, Park, Nelson, Horvath & Palmes (1950).
(3) With rising environmental heat load, the action of the various heat loss mechanisms seems to take place in a sequential manner emphasising several "lines of defence". In a temperate environment body cooling occurs principally by radiation and convection. As the environment becomes warmer, skin evaporation is intensified, which in turn becomes supplemented in a progressive way by respiratory evaporation. This sequence, incidentally suggests a sequence of rising caloric expenditure per unit of cooling achieved. Losing calories by radiation and convection is an inexpensive way of cooling; losing them by the activity of sweat glands is probably more expensive; and losing them by forced convection from the respiratory tract is a most expensive way because it involves muscular activity. Cooling by a high respiratory activity not only has the disadvantage of being a heat producing process itself, but also one which may affect the acid-base status of the body by the elimination of an excessive amount of carbon dioxide (Dale & Brody, 1952; Bianca, 1955).
(4) A further complicating factor arises from the fact that the process of losing heat by radiation or convection has a thermal reversal point. In an environment below skin temperature there is a thermal flow from the animal to the environment. Once the environment becomes warmer than the skin, the thermal flow becomes reversed. Consequently, radiation and convection, at first avenues of heat loss, become avenues of heat gain.
(5) Finally, it is known that respiratory frequency, with increasing heat stress, acts in a discontinuous way. It rises rapidly to a maximum; if the demand for cooling continues to be high, it then declines (Findlay, 1957; Bianca, 1958). As the minute volume of respiration rises continuously throughout, this means that a given respiratory rate, say 150 respirations per minute, has a different significance as regards ventilation, in the rising phase from what it has in the declining phase.

These considerations show that it may be difficult to assess correctly what the action of a given isolated heat response means to the animal in terms of actual heat strain.

Bearing in mind difficulties of this kind, it may be postulated that a body function, eligible as a criterion for a heat tolerance test, should fulfil the following requirements:

(1) It should be meaningful, i.e., directly related to the body's thermoregulation and consequently truly representative of the strain the animal may experience in a hot environment.
(2) It should respond to envrionmental heat in a ready and reproducible way, i.e., show a clear dose/response relationship.

(3) Its measurement should be accurate, quick, simple, and inexpensive.
(4) It should have a normal base line, i.e., show relatively little variation in a temperate climate, both within and between animals,thus affording a proper base for any changes that might occur due to heat.
(5) It should be applicable also in the young animal, thus allowing an early prediction of an adult animal's heat tolérance.

When considering various animal functions, it is evident that body temperature meets these requirements best. In particular, body temperature is an expression of the body's thermal balance, since all heat gain and heat loss processes of the body are ultimately reflected in its temperature.Indeed,body temperature indicates in a single figure to what extent the thermoregulatory mechanisms have been successful in maintaining homeothermy. With regard to its measurement deep body temperature is adequately represented by the temperature of the rectum (Bligh, 1957).

There are three objections which might be raised against using body temperature as a criterion of heat tolerance.

(1) In heat stressed man breakdown may occur without the body temperature being much elevated (Bean & Eichna, 1943). Here, body temperature obviously would be a poor incicator of heat tolerance. This behaviour,however,is probably more typical of man than of cattle. In man,who has an erect body posture and who sweats profusely,circulatory failure may develop before hyperthermia. In the bovine animal which has a non-erect posture and which sweats only moderately,this is not known to happen.Whenever cattle are distressed by heat,as evidenced by various signs such as profuse salivation,high respiratory activity and anorexia, body temperature is invariably above normal.
(2) It might be questioned whether a rise in body temperature in a heat exposed animal would necessarily be a sign of heat intolerance.Might not a labile body temperature, at least within certain limits, be a means of losing heat, by establishing a larger gradient of heat flow between the body and its environment? Schmidt-Nielsen,Schmidt-Nielsen, Jarnum & Houpt (1957) express the view that a high body temperature in heat exposed cattle may be indicative of a high heat tolerance,and that in consequence,it may be unwise to select cattle for hot climates on the basis of a non-elevated body temperature. Schmidt-Nielsen et al. (1957) have shown that the camel's body temperature may have a daily variation in excess of 6°C. This variation does not indicate a failure of temperature regulation but is part of a well-regulated physiological mechanism for the conservation of water.While the camel seems to be adapted by evolution to tolerate an elevated body temperature without distress,or even without an increased respiratory activity,the same cannot be said of cattle. In cattle a body temperature significantly above normal is always accompanied by a number of obvious signs of heat distress. It may be noted that the variation in the camel's "normal"body temperature covers the range 34° to 41°C, i.e.,it extends to very low temperatures.Thus,starting the day following a cool night with a body temperature of say, 34°C, would give the camel the advantage of a low "starting point" for the subsequent heating up period during the day. The possibility of a similar thing happening in cattle,although on a much reduced scale, has been discussed by Bianca (1959).
(3) Rapid changes of the thermal environment are not immediately reflected in the body temperature measured per rectum.Changes occur with a lag,and this lag increases with increasing size of the animal.This difficulty, however, may be largely overcome by a well-defined technique for measuring heat tolerance and by not comparing"incomparable" quantities. It is commonsense, for instance, to avoid a direct comparison between a small calf and a big bull, with respect to their tolerance time in an acute exposure to severe heat.

It would thus appear that body temperature,when properly used, is the best single physiological criterion of heat tolerance.

ECONOMIC TRAITS

The production of milk and of beef are physiological activities which are related to heat tolerance in two ways:

(1) They involve the generation of extra heat, which reduces the capacity for heat tolerance.

(2) They become depressed when the environment is very hot,which favours heat tolerance.

Should then, in view of this relationship,these economic traits be used as indicators of heat tolerance? Or indeed,should one go directly for the production of milk and meat, which after all are what cattle are bred and kept for, and dismiss heat tolerance altogether? Cartwright (1955) has found weight-gain in summer a more useful indicator of heat tolerance than rectal temperature,respiratory rate and heart rate,and Vernon, Damon,Harvey, Warwick & Kincaid (1959) in Louisiana have postulated that the selection of beef cattle on the basis of production automatically also includes sufficient selection for heat tolerance. Although this approach has much to recommend it, it also has its limitations, especially with respect to milk yield.

The most obvious limitation, of course, is that milk yield cannot be tested in young animals. This excludes the prediction of an animal's future performance from a calfhood index. Furthermore, milk yield is affected by a hot environment in an indirect way: a decline in milk yield is preceded by a decline in voluntary food intake. There seems to be no immediate effect of hot weather on milk production as long as food consumption is not affected (Johnston, 1958). At what magnitude of environmental heat load animals will begin to reduce their voluntary food intake,depends on their heat tolerance.European breeds have a lower threshold value than tropical breeds (Worstell & Brody, 1953),and there seem to be differences also between animals of the same breed.Thus,of two cows which have the same genetic capacity for milk yield,the one with the higher capacity for heat tolerance will be the better producer in a hot environment.It is possible that the reduction in voluntary food intake applies in the first place to food with a high fibre content,the digestion of which produces much waste heat. In this case a ration containing a high proportion of concentrates should be expected to interfere less with appetite and thus with milk production. There also seem to be individual cows whose "physiological wisdom" does not induce them to subordinate milk secretion to temperature regulation. They seem to do this, however, at the expense of a high body temperature.Payne & Hancock (1957) have reported such a case. It could be that this is the type of animal one should select for.On the other hand milk produced from cows in a febrile state may not be qualitatively satisfactory and the animal itself, under the double burden of producing large quantities of milk and combating heat at the same time may have a lowered resistance to disease and other stresses.

It may be said in conclusion that productive performance seems to be useful as an indicator to heat tolerance or indeed, as a quantity in its own right with beef cattle,but that it appears to be less useful in these respects with dairy cattle.

METHODS FOR GRADING HEAT TOLERANCE

GENERAL

There are two ways of expressing an animal's heat tolerance. (1) One may ask: How much does a certain body function change when the animal is exposed to a standard hot environment? This is the commonly used way, or (2) one may ask: Which heat load must be imposed on an animal in order to evoke a standard change in body function? This way is less common with respect to climate, but it is often used for testing tolerances to other stress producing agents. The tolerance to alkali, for instance,is measured by the amount of alkali that must be given in order to cause an alkaline urine. Both ways have merits and limitations, as may be seen from the following comparison.

The first way, which expresses heat tolerance in terms of animal response, has the advantage of being relatively easy to perform and of giving a precise numerical answer. It is, however, limited in its interpretation.

The second way, which expresses heat tolerance in terms of a thermal environment, is less easy to perform and normally less precise in its result, because it requires each animal to be exposed in succession to a series of different environments possibly with interpolation to be made between the two nearest environments. On the other hand, it is more meaningful in its interpretation. It may result, for instance, in the statement that the animal under investigation is capable of tolerating an environmental temperature of X degrees before showing a certain standard response. This knowledge in turn may be of use in predicting this animal's reaction to the thermal conditions prevailing in a certain geographical region. Which of these two ways of expressing heat tolerance will be adopted depends largely on the special problems and the facilities available.

The following pages are devoted to a brief description of various tests which have been used or advocated for use in assessing and grading heat tolerance in cattle.

WATER EXPENDITURE TEST

Rhoad (1940) under field conditions measured parameters indicative of an animal's water loss through various channels, namely:

(1) respiratory rate, as an index of moisture loss from the respiratory tract;
(2) loss of moisture from selected skin areas;
(3) nitrogen concentration of the urine, as an index to water expenditure through the kidneys;
(4) moisture content of the faeces, as an index to water expenditure through the excreta.

The test periods ranged from 1 to 10 hours with an average of 3 hours. Water at atmospheric temperature was available at all times.

This is a most useful approach to an important side of the heat tolerance problem and Rhoad has been able to demonstrate with his method clear breed differences. It seems, however, that the method, even in the simplified field version used, is too complicated to be adopted as a heat tolerance test proper. On the other hand it does not measure an animal's water loss accurately enough. Rhoad probably did not intend to use the results of these measurements as components of a heat tolerance index, since he did not condense the data into any formula. For judging the "efficiency of heat disposal" Rhoad relied on the behaviour of rectal temperature, which, at a later stage, he extended to the Iberia heat tolerance test.

IBERIA HEAT TOLERANCE TEST

In this test, developed by Rhoad (1944) one determines how much the rectal temperature of an animal exceeds 101.0°F (38.3°C) when the animal is exposed in the open field to the thermal conditions of a calm clear day with a shade temperature between 85° and 95°F (29° and 35°C). The rectal temperature measurements are taken at 10.00 and 15.00 hours on three consecutive days and the results averaged. By using the formula

$$100-\left[10\ (\text{mean rectal temp.} - 101.0)\right]$$

the result is expressed as a percentage of maximal efficiency in maintaining rectal temperature at 101.0°F, the average rectal temperature of cattle. Respiratory rate, which is counted at the same time, may be used as an additional criterion to differentiate between two animals showing the same rise in rectal temperature. The animal with the least rise in rectal temperature (and the lowest respiratory rate) is considered the most heat tolerant.

This test is based on a sound principle and is easily performed. It has been used extensively for differentiating between the heat tolerance of various breeds of cattle.

While it is thus a most useful test for field conditions, it has certain limitations which must be borne in mind when it is used for work demanding a higher degree of accuracy. The two main limitations are: (1) that the environmental conditions are not sufficiently standardized and (2) that 101.0°F, being an average figure for rectal temperature of cattle, does not make allowance for normal variation of this parameter due to age, breed, level of feeding, level of production, etc. The first point becomes apparent, for instance, in a comment by Phillips (1948) on an interbreed comparison: "These results cannot be considered conclusive evidence of superior heat tolerance in breed X, since the environmental temperature at which tests were made were somewhat lower than in the breed Y, and these differences may have been sufficient to distort the results". With regard to the second point it is particularly important to make allowance for the fact that, other factors remaining equal, young animals tend to have a higher normal body temperature than adult animals. So, if a young animal has a normal body temperature of, say 102°F, rising to 104°F under the influence of a hot environment, its heat tolerance figure is 70 if calculated on the basis of 101°F, but 80 if calculated on the basis of 102°F. In other words, the test tends to give falsely low figures for young animals due to their higher initial level of body temperature. Conversely, the test tends to give falsely high figures for animals whose normal body temperature is below 101.0°F. This dependency of the result of the Iberia heat tolerance test on the animal's normal body temperature may be further exemplified by a report of an investigation of the heat tolerance of a group of young animals (0-1 years) and that of a group of older animals (1-4 years). The test yielded 77 for the young group and 89 for the older group. If the heat tolerance of the two groups are computed on the basis of the body temperatures actually measured in these animals in a temperate environment, figures of 79 and 86 are obtained. This means that the difference in heat tolerance between the two age groups shrinks from 12 to 7 units, i.e. it becomes almost halved. It has to be realised, of course, that it may be very difficult or even impossible under field conditions to obtain a "normal" body temperature, in which case recourse must be had to a fixed standard figure.

R-VALUE HEAT TOLERANCE TEST OF LEE

Lee (Phillips & Lee, 1948) developed what he termed a laboratory analogue to the Iberia heat tolerance test. Essentially, it consists of a 7 hr exposure of the animal to a series of atmospheres at different known temperatures and humidities. The rectal temperature is measured periodically and an expression of its mean behaviour, called R-value is calculated.

The R-value represents the area between the abscissa and the curve in a time-rectal temperature diagram. From the R-value for the different combinations of temperature and humidity the value of the constants a, b and c in the equation $\text{Log } R = at + bh + c$, where t is temperature and h is vapour pressure, may be calculated. The values of a, obtained upon two different animals indicate the relative fashion in which the rectal temperature rises in response to atmospheric temperature for a given humidity, and those of b in response to a rise in atmospheric humidity, for a given temperature, over the range of conditions used in the series of experiments. Similar procedures can be adopted with respect to respiratory rate, pulse rate, etc.

This test has the merit of a controlled environment and an integrated response of the animal. On the other hand whether an animal was in a steady or in a rising phase with regard to the parameter investigated cannot be derived from an isolated R-value. Furthermore, if, as a result of a too rapidly rising body temperature, an animal has to be removed from the test atmosphere before the 7 hours of exposure have elapsed, an extrapolation technique has to be used (Robinson & Klemm, 1953).

BENEZRA'S COEFFICIENT OF ADAPTABILITY

Benezra (1954) postulates a summation of the body temperature response and the respiratory rate response by using the formula body temperature (in ^{o}C)/38.33 + respirations per min/23 = 2. A value of 2 would represent the norm or a state of maximal adaptability, a value above 2 a state of a lower adaptability. While it seems a reasonable idea to take into consideration also an animals respiratory response, it is not correct to give it equal weight with the body temperature response. A 10% increase in body temperature i.e. to 42.2^{o}C, would eventually cause death, while a 10% increase in respiratory rate i.e. to 25 respirations per min is physiologically meaningless and probably even lies within the counting error.

LINES OF EQUAL EFFECT

Barrada (1957) constructed empirically lines of equal effect by charting separately the reactions of rectal temperature, respiratory rate and respiratory volume of cattle to different combinations of wet and dry bulb temperature in a temperature-vapour pressure diagram. He found that these lines change their slope as one passes from cooler conditions to hot conditions in much the same way as those obtained for humans. This is a very useful concept for the description of the combined effect of temperature and humidity on physiological reactions. The procedure may, however, be too elaborate to be used as a test of heat tolerance.

VARIOUS TESTS OF ADAPTABILITY OF CATTLE TO LIFE IN HOT COUNTRIES

Bonsma (1949) has described a number of procedures which are not heat tolerance tests in the strict sense of the word, but tests which give valuable information on an animal's general capacity to live in a hot country under ordinary field conditions.

In the "felting test" a sample of hair is taken from the animal, damped with water and rubbed between the hands. If the hair forms a firm mass, i.e. felts, this indicates a smooth coat, if the hair rubs away, this indicates a woolly coat. Confirmatory evidence of this behaviour of the two types of coat was obtained by subjecting the hair samples to a felting process in a wool factory and testing the resistance of the compressed hair mass to a pulling force. According to Bonsma a woolly coat is associated with a low heat tolerance and a smooth coat with a high heat tolerance. Thus, examination of a hair sample would afford a simple means for judging indirectly an animal's heat tolerance. Apart from its simplicity such a method has the merit of being applicable to very young animals and not requiring exposure to a hot environment.

The work of Bonsma can hardly leave any doubt that there is a definite association between coat character and heat tolerance; also the work of Yeates (1955), Dowling (1959b) and that of Turner & Schleger (1960) leads to the same conclusion. It would be desirable, however, if the coat characters could be expressed in a more quantitative and objective way and if the nature of this association could be further elucidated. It is for instance not entirely clear to what extent it is a dense coat per se that depresses heat tolerance by interfering with heat loss from the skin, and to what extent a dense coat is only the outward sign of an inner function, probably of endocrine nature, more directly related to heat tolereance. Thyroid activity, for instance, is known to affect hair growth as well as heat production which in turn influences heat tolerance. It could be speculated that a thin coat could be a "byproduct" of the chain of events, connecting atmospheric heat, over depressed thyroid activity, reduced metabolic rate and lowered heat production with increased heat tolerance. There is also the possibility that in contrast to the more obvious case that the coat affects the heat tolerance, the heat tolerance could affect the coat. This could be the case, for instance, when an animal with a low heat tolerance would reduce its food intake which would then cause a state of malnutrition and of lowered resistance to disease, leading to changes in coat character.

In "walking tests" and in "water deprivation tests" Bonsma (1949) demonstrated the superiority of African cattle over European type cattle in covering long distances and in going without water over certain periods of time, in a semiarid region.

"COOLING EFFICIENCY" TEST OF DOWLING

Dowling (1956) considers the Iberia heat tolerance test as unsuitable in the hot dry inland climate of Australia, because the excessive solar radiation may cause loss of control of body temperature regulation in the animals, in which state, in Dowling's opinion, body temperature would not be a meaningful criterion of adaptability to heat. He therefore proposes a heat tolerance test which should be based solely on an animal's capacity for dissipating excess body heat, without the complication of a simultaneous heat load from solar radiation. His procedure is as follows: The animal is exercised on a warm day for about half an hour until the rectal temperature reaches about 40°C (104°F), after which it is allowed to stand in the shade to cool down. The rate of cooling is followed by periodic measurements of rectal temperature. The animal which shows the highest rate of decrease of body temperature is considered to have the highest "cooling efficiency".

The concept of cooling efficiency is, no doubt, an interesting one. It would appear, however, that the higher the intensity of solar radiation the more important it would become for an animal not only to have a high capacity for dissipating heat but also to have structural features, especially of the coat, which oppose the absorption of radiant energy from the sun. When devising a heat tolerance test for animals living in a region where solar radiation is excessive, thus constituting the limiting climatic factor for heat tolerance, it would seem to be more realistic to include this very factor in the test than to exclude it. In order to avoid the development in the animal of serious hyperthermia, the duration of each test would, of course, have to be restricted in time. Although in a test based on a short exposure to an extreme heat load, as Dowling has realized, the animal is in a state of acute thermal imbalance, the result of such a test may still be of value because it includes the effect of the principal stress producing climatic element, which, in this case, is solar radiation.

PREDICTED HEAT TOLERANCE FROM CALF TOTAL MOISTURE VAPORISATION RATES

Yeck & Kibler (1958) reported that the ratio total evaporation (skin plus respiratory) in an environment of 27°C/total evaporation in an environment of 10°C, correlated very well with the relative heat tolerance of calves of 6 different breeds. The highest ratio (2.75) and the highest heat tolerance were found in the Brahman; the lowest ratio (1.35) and the lowest heat tolerance in the Shorthorn, with the other breeds in between in the following order of falling heat tolerance: Santa Gertrudis, Brown Swiss, Jersey, Holstein. These ratios changed very little for each breed with advancing age.

This is an impressive demonstration of the role played by evaporative cooling in the thermoregulation of cattle. As the accurate measurement of total evaporation is a fairly elaborate procedure it may be simpler to assess heat tolerance by a more easily measurable character such as body temperature.

HUMAN HEAT STRESS INDICES

The literature contains a number of indices devised to assess the severity of hot climates or the physiological strains resulting from them in man. The best known of these indices are:

(1) Effective temperature, Houghten & Yaglou (1923).
(2) Standard operative temperature, Gagge (1940).
(3) Index of physiological effect, Robinson, Turrell & Gerking (1945).
(4) Corrected effective temperature, Bedford (1946).

(5) Predicted four hour sweat rate, McArdle, Dunham, Holling, Ladell, Scott, Thomson & Weiner (1947).
(6) Heat stress index, Belding & Hatch (1955), and
(7) Singapore index, Webb (1959).

These indices are mostly highly specific for humans. They make use of constants derived from humans; some depend on the sensation of warmth rather than objective measurements of physiological reactions of the test subjects; the predicted four hour sweat rate, which at present is considered the best index, is based on sweating, a heat response which in cattle does not play an equally dominating role as it does in man; and there is also the complication arising from the consideration of modifying factors such as clothing and physical activity.

These human heat stress indices, therefore, are not readily applicable to cattle. A possible exception may be the index of physiological effect, which may be modified to suit cattle.

From this description of various methods for grading heat tolerance it would appear that many of them provide useful information but that none of them is entirely satisfactory. Rhoad's "classical" Iberia test probably is still one of the best. In view of the necessity to select cattle for hot climates there is a definite need for an improved method for assessing heat tolerance.

FACTORS WHICH MODIFY HEAT TOLERANCE

GENERAL

Every animal character is a function of heredity and environment. Heat tolerance as an aid to selection for subsequent breeding is of interest only as far as it is genetically determined. The genetic potentialities for heat tolerance can only find their full expression in the presence of appropriate conditions of nutrition, management and disease control. Furthermore, heat tolerance depends on factors which will or may vary during the life of the individual, such as age, state of activity, level of production, and acclimatization. In some cases these factors have to be accepted, as they are; indeed, they may be pertinent to the problem under investigation. It is important, therefore, to know which factors influence heat tolerance and to what extent they do so. Once this is known one can either standardize these factors, or, if this is not possible, eliminate their effects by making suitable adjustments. Although it is realised that many of these factors are inter-related it is convenient to discuss each of them separately.

AGE

A few preliminary remarks of general character may be appropriate. Tolerance is the reciprocal function of sensitivity (Loewe, 1959). The young animal tends to be more sensitive in that it reacts more violently than the adult animal to an environmental stimulus of a given strength; it shows, in other words, a greater response. If one accepts this as being true also with regard to atmospheric heat as a stimulus, the young animal, by definition, would be less heat tolerant than the adult animal.

This statement, however, depends on two assumptions: First, that the young and the adult animal have the same range, i.e., functional capacity of response, and second, that a given deviation from the norm (of a given response) means the same to the young as to the adult animal with respect to discomfort and damage. There is some evidence against these assumptions. As regards the first point, it is known that young animals, when exposed to severe heat, have a higher maximum level of respiratory rate than adult animals. Thus a

respiratory rate of, say 180, might represent 70% of the young animal's, but 100% of the adult's full capacity. Similar conditions probably exist for heart rate.

The second point actually ties up with the first point. The discomfort experienced or the damage caused by a given level of response, probably depends on the maximal level of this response, meaning that the young animal working at, say 70% of its capacity is less stressed than the adult animal working at say 100%.

The obvious answer to this problem would be to express a heat response as a fraction of its maximal value. The assessment of the maximum value of a heat response does not present much difficulty with respiratory rate;it would also be possible with skin evaporation; it could, however, be dangerous for heart rate and certainly would be lethal for body temperature.

To what extent these points have to be taken into consideration in assessing heat tolerance in cattle of various ages cannot be decided at present.More work on the dose/response relationship of animals of different age groups is needed.In the meanwhile,the same conventional concept of heat tolerance will be used for judging the heat performance of cattle of different age groups.

Heat tolerance has been shown by various workers to increase with age.Klemm & Robinson (1955) found falling R-values for rectal temperature in Australian Illawara Shorthorns and in Zebu-Hereford crosses from 2 to 12 months of age. Walker(1957),using the heat tolerance test of Rhoad (1944), noticed a general rise of heat tolerance in Africander,Angoni, Barotse and Tonga cattle between the ages of 1 and 4 years, the largest rise occurring between 1 and 2 years. In Jersey cows ranging in age from 2 to 6 years and over, Galaas (1947) found the lowest heat tolerance in the 2 to 3 year class,the highest in the 3 to 4 year class. Bonsma (1949) concluded from his extensive investigations carried out in South Africa on cattle of various breeds and types: "The work indicates beyond all doubt, that an animal's heat tolerance coefficient increases considerably,especially after the second year".

The increase in heat tolerance with age does not occur in a linear way.The increase appears to be largest between calfhood and adulthood.In the adult animal heat tolerance,if not complicated by other factors such as level of production,seems to remain fairly stable. Whether heat tolerance decreases in the old animal,as one might expect it to do, is not known.When comparing the age-heat tolerance relationship of various breeds of cattle it is important to bear in mind that the chronologic age of an animal need not be identical with its physiological age.Tropical breeds tend to be later maturing than temperate breeds.

The problem of the influence of age on heat tolerance needs further investigation; not only because the problem is of immediate practical importance,but also because the knowledge of the age-heat tolerance relationship may help the nature of heat tolerance to be better understood. If we find that heat tolerance shows a significant increase from say half a year to 2 years,this must be accompanied by corresponding structural or functional changes in the animal, taking place over the same period. Characters which during this period do not change or even change in the wrong direction obviously cannot be made responsible for the observed changes in heat tolerance. This consideration would apply to sweat gland density, i.e. the number of sweat glands per unit of skin surface, which has been shown to decrease with age (Findlay & Yang, 1950; Carter & Dowling, 1954; Walker, 1957). It would also apply to the surface mass ratio of the animal, to the capacity for maximum respiratory rate, and to the amount of subcutaneous fat, all of which with advancing age tend to change in the direction of a lowered capacity for heat tolerance.

On the other hand there are body functions which tend to change with age in the direction of an elevated heat tolerance.Skin evaporation,in spite of a decrease in sweat gland density and probably due to an increase in the size and the efficiency of the individual sweat gland, increases with age (Klemm & Robinson, 1955; Kibler & Yeck, 1959). Heat production per unit body weight declines with age (Kibler,1957) and this seems to be paralleled in part by a decrease in thyroid activity (Blincoe,1958; Lennon, 1958). Closer in-

vestigation of these functions may lead to a better understanding of the factors that control heat tolerance in cattle.

NUTRITION

Nutrition can affect heat tolerance in several ways.

(1) A high plane of nutrition is associated with a high resting metabolic rate, which in turn depresses heat tolerance. Robinson & Lee (1947) have reported that sheep,pigs and hens on a high plane of nutrition had a reduced heat tolerance as indicated by elevated levels of body temperature, heart rate and weight loss during the test. Similarly, Yeates (1956) found well fed cattle to be less heat tolerant than poorly fed cattle,the respective heat tolerance coefficients (Rhoad, 1944) being 43 and 55. The work of Sorensen, Hansel, Hough, Armstrong, McEntee & Bratton(1959) suggests that an increased thyroid activity is involved in this elevated resting metabolic rate of cattle on a high plane of nutrition.
A high level of nutrition may reduce heat tolerance not only by raising resting metabolic rate, but also by causing interference with heat loss through the deposition of fat under the skin.In this context it is of interest to note that Zebu type cattle, seem to lay down body fat preferentially in the interior of the body, while European type cattle do so under the skin (Ledger, 1959).

(2) The processes of prehension, mastication,digestion,absorption and metabolism of food generate heat, which again depresses heat tolerance. While these processes are going on, especially in the early phases, body temperature,heart rate and respiratory rate of calves are elevated, even in a temperate climate (Bianca, unpublished data). Conversely,starvation is accompanied by a fall in heat production and heart rate (Blaxter & Wood, 1951). Furthermore,it has been shown by Yeates (1956) that the important factor in the feeding/heat tolerance relationship is the current rate of feeding. In other words, it is relevant how much the animal,whether lean or fat,has eaten shortly before the performance of a heat tolerance test. An adequate period of starvation before a heat tolerance test is therefore essential for obtaining reproducible results. On the other hand, since animals,in order to live and produce, have to eat,it is, with respect to heat tolerance, important that the various processes associated with the intake, digestion and absorption of food, produce a minimum of waste heat. Obviously the animal which does so, i.e.,which utilises food efficiently,must be more heat tolerant than an otherwise similar animal which utilises food less efficiently. This applies in particular to roughage since this contributes the bulk of the food and requires much energy for its breakdown.

(3) The composition of the food may affect heat tolerance. Cows and buffaloes fed on hay had significantly lower respiratory rates than animals fed on straw (Badr,1957). Similarly, a ration with a low fibre content,as compared to one with a high fibre content, had a beneficial effect on the performance of cows in Arizona when air temperatures exceeded about 27°C (81°F): respiratory rate was lower by 14 beats/min and body temperature by 0.5°F (0.3°C).The production of fat corrected milk was higher by 1.2 lb per cow and day (Stott & Moody, 1960). According to Page,Erwin & Nelms (1959) cattle which were deprived of vitamin-A reserves were unable towithstand high summer temperatures.It was also shown that the hot climate itself was the predisposing factor for a low vitamin A level; calves maintained at a high ambient temperature lost three times as much vitamin A from their livers than their co-twins at a normal temperature. Similarly,rabbits deficient in vitamin A had areduced time of survival when exposed to heat (Kurokawa, 1941).Mineral deficiencies in the food may likewise affect body structures and functions which play a role in thermoregulation.

The depressing effect of a high food intake on heat tolerance does not continue without counter-action.With rising environmental temperature food intake is reduced and eventually completely suppressed. This means, that food intake acts as a temperature regulating

mechanism, i.e., that the amount of food eaten is determined, at least partly, by the organism's ability to dissipate the heat of food metabolism, as has been suggested by Brobeck (1948). This regulating action of appetite should be expected to set in earlier, i.e., at a lower environmental temperature, in heat intolerant animals than in heat tolerant animals. There is some evidence that heat anorexia occurs earlier in European type cattle than in tropical cattle (Johnson, Ragsdale & Yeck, 1958).

While heat tolerance is affected unfavourably by a high food intake, it is affected favourably by a high water intake, because water is the indispensable raw material for evaporation, which plays a vital part in heat tolerance. A high water intake in itself does not necessarily guarantee a high heat tolerance. Consuming cool water, warming it to body temperature and excreting it through the kidneys will, of course, have a cooling effect. Indeed, the "famous" Jersey cow 212 (Thompson, Worstell & Brody, 1949) when exposed to an environment of 38°C (100°F), by drinking the unusual amount of 195 litres of water per day, in this fashion rid herself of over 4,800 kcal per day. Yet, evaporating the water instead of circulating it through the body, is a much more efficient way of utilizing the cooling potentialities of water. If all the 195 litres of water could have been evaporated, the cooling effect would have been about 23 times greater. Kibler and Yeck (1959) expressing vaporized water as a percentage of consumed water, found higher percentages in Santa Gertrudis and Brahman cattle than in Shorthorn cattle, indicating that the former two breeds were more efficient in utilizing consumed water for evaporative cooling. It thus appears, that consuming more water than the organism can readily evaporate is of relatively little value to the body, with respect to heat tolerance.

The effect of a deficiency of water on heat tolerance is not sufficiently known. If cattle, exposed to heat and at the same time deprived of water would behave the same way as man is known to behave under similar circumstances, they would keep up a high rate of evaporation and consequently dehydrate their body. In such a case, heat tolerance would not be lowered at least not until dehydration would affect other body functions which play a part in thermoregulation.

ACTIVITY

Physical exercise produces extra heat which has to be eliminated from the body; it is thus inversely related to heat tolerance. It is obvious, therefore, that heat tolerance tests should be carried out only in well rested animals. In a hot environment animals tend to reduce their activity; but in search of food and water they have to do a certain amount of walking, especially when the grazing is scarce and the number of water places restricted, as is frequently the case in hot countries.

The degree to which exercise depresses an animal's heat tolerance depends largely on its body build and its state of training. A slim, long legged "respiratory-type" animal will experience less thermal discomfort than a bulky, short legged, "digestive type" animal when covering the same distance, and both types will perform their task progressively in a more efficient way as their bodies get used to the exercise. Striking differences in walking capacity between Shorthorn and Hereford cattle on the one hand, and Afrikaner cattle on the other, have been demonstrated by Bonsma (1949). The superior performance of the Afrikaners - they could walk farther and showed less elevation in their body temperature - seems to have been due partly also to the smoothness of their coat, which allowed a better heat dissipation from the skin.

REPRODUCTION

It is known that the body temperature of cows fluctuates with the oestrus cycle (Wrenn, Bitman & Sykes, 1958; Fallon, 1959). The temperature is lowest just before heat, high on the day of heat, low again at the time of ovulation, and high during the luteal phase of the cyle. The difference between the lowest and the highest rectal temperature during

oestrus cycle can amount to half a degree F.This temperature pattern has been attributed to the thermogenetic influence of endogenous progesterone.

Body temperature is also affected by pregnancy; it is at a higher level and a few days before calving there is a precipitous decline of about 1.0^{o} to 1.6^{o}F (0.6^{o} to 0.9^{o}C)(references under Wrenn et al., 1959).

Thus, under these conditions "normal" body temperature will differ considerably from what might be expected in a "normal" animal.This would introduce an element of uncertainty into any heat tolerance test that contained normal body temperature as a base of reference. Furthermore,the specific physiological changes of the body associated with oestrus and pregnancy are likely to affect an animal's capacity for tolerating a hot environment.

LEVEL OF PRODUCTION

An animal with a high level of production has a high heat production and consequently a low heat tolerance. Each lb of fat corrected milk produced by the animal increases metabolic heat production by approximately 10 kcal per hour. A 1,000 lb cow with a resting heat production of 500 kcal per hour,producing 50 lb of fat corrected milk per day would have a total metabolic heat load of 1,000 Calories per hour, or double the resting heat load (Johnston, 1958). The level of production, of course,is closely related to the level of feeding. As the food intake becomes voluntarily reduced in a hot environment the production goes down. These two changes, however, may be somewhat out of phase with each other. The results obtained by Worstell & Brody (1953) suggest that the fall in food intake precedes the fall in production which then leads to a loss in body weight.

As a consequence of this dependence of heat tolerance on milk yield the same animal will give different results of heat tolerance according to whether it is dry or lactating and while it is lactating the result will vary with the amount of milk produced.Similarly, high producing and low producing animals (of the same breed or of different breeds) will vary among each other in heat tolerance. This, of course, makes the interpretation of any heat tolerance test difficult and calls either for comparisons to be made only at the same level of production, or for correction factors to be used.

While the level of production, plays an important role in heat tolerance it is by no means the only factor involved.The superior heat tolerance of tropical cattle is not entirely the result of their lower level of production. As shown by Johnston, Hamblin and Schrader (1958), for the same level of milk yield, Red Sindhi crossbreds were more heat tolerant than European type cattle. If Zebu cattle produce milk at the same caloric cost as European cattle, which seems a reasonable assumption to make,their superiority in heat tolerance would be the result of a lower resting metabolic rate, of a higher loss or of both.

ACCLIMATIZATION

When an organism is repeatedly or continuously exposed to an environment hotter than that normally experienced, it may develop functional and structural changes which result in an increase in its ability to live without distress in a hot environment. A heat acclimatized organism is thus an organism which has reached its maximal heat tolerance.

There is ample evidence of heat acclimatization in man, but little in cattle. Calves, in response to repeated short exposures to a hot dry and to a hot humid environment show progressive reductions in rectal temperature,skin temperature and heart rate, as well as changes in respiratory activity (Bianca, 1959a, b).

A special case of acclimatization is that due to season.In regions where there are pronounced seasonal climatic changes the animals go through cyclic phases of acclimatization and de-acclimatization.As these seasonal climatic changes occur very gradually,the animal has ample time to undergo adaptive changes. The most evident among these changes is that

of the hair coat. A heavy winter coat interferes with heat dissipation and therefore depresses heat tolerance; a light summer coat interferes less with heat dissipation and therefore conveys a higher degree of heat tolerance to the animal. Dowling (1959b) has shown that the heat tolerance of the same animal at different seasons can be attributed to changes in the hair coat. Yeates (1955) has observed that the principal climatic factor responsible for these seasonal changes is the duration of daylight, and has shown (1957) that the equatorial photoperiod eliminates the natural coat cycle of European cattle, tending to maintain them in a heat retaining type of coat. Seasonal acclimatization probably also involves changes in thyroid activity and in metabolic rate, so that the effect on heat tolerance may be one of heat loss as well as of heat production.

In view of this dependence of heat tolerance on the state of acclimatization it is imperative that animals which are compared for heat tolerance are in a comparable state of acclimatization. This may be achieved either by artificial acclimatization or by testing all animals in the same season. The importance of the latter procedure is well exemplified by the work of McDowell, Matthews, Lee & Fohrman (1953). These authors, when conducting a series of heat tolerance tests found that the repeatability coefficients for rectal temperature responses in Jersey heifers remained fairly low until the data had been sorted into seasonal groups. Under the climatic conditions prevailing in Louisiana the maximum response of rectal temperature occurred in February, the minimum response in May-June. The observation that the response of rectal temperature to an acute heat stress was also elevated in August, points to a partial loss of heat tolerance at the end of a long continued period of summer heat. The same tendency has been observed in calves at the end of a series of short daily exposures to severe heat (Bianca, 1959a). Thus, a state of "over-acclimatization" may develop whenever the forces of adaptation become exhausted. This emphasises the importance of employing the correct "dose" of heat when acclimatizing animals.

MANAGEMENT

Most managerial devices such as sun shades, fanning, etc., are means for reducing environmental heat load on the animal by providing a suitable microclimate. Proceeding in this direction would ultimately lead to air conditioned byres, in which case heat stress would be completely eliminated and heat tolerance no longer a character looked for in animals. Thus, these devices do not affect the heat tolerance of the animal.

There are, however, managerial procedures which do affect an animal's heat tolerance, if only temporarily. Cooling of the drinking water which has already been mentioned in the section on nutrition and the use of showers are examples of this type of procedure. A longer lasting effect on an animal's heat tolerance is achieved by clipping its coat. The magnitude of this effect seems to depend on various circumstantial factors. Clipping a heavy (winter) coat was found to be more effective than clipping a light (summer) coat (Bianca, 1959c). Similarly, clipping a coat of non-medullated hair improved heat tolerance more than clipping a coat of medullated hair (Dowling, 1959b). Clipping the coat resulted in a significant increase in skin evaporation of crossbred cows in Israel (Berman, 1957), but it affected only slightly the thermoregulatory reactions of heat acclimatized dairy heifers kept in a hot room at 32°C (89°F) (Berman & Kibler, 1959). The effects of clipping are qualitatively comparable to those of seasonally induced coat shedding. They are, however, more pronounced because the change is more complete and it occurs more abruptly. It is self-evident that clipping affects heat tolerance in a favourable way only in the absence of intensive solar radiation. In its presence the bare skin absorbes more radiant heat than the hair covered skin which results in a lowered heat tolerance.

STATE OF HEALTH

In man impairment of physical fitness tends to reduce performance in a hot environment (Bean & Eichna, 1943). Fitness in this context probably extends primarily to the circulatory system which, certainly in profusely sweating man, bears the main burden of heat dis-

sipation.Herrington (1952)has even suggested that heat tolerance might be predicted from exhaustion times in work under cool conditions.

In cattle the state of physical fitness is not easily assessed and it is not certain whether circulation plays an equally important role for heat dissipation in cattle as it does in man.

Riek, Hardy, Lee & Carter (1950)found that heat tolerance in sheep kept on various levels of nutrition was not highest at the lowest level of nutrition,as might have been expected, but at the medium level of nutrition. They thought this to be due to the inefficiency of all body functions including the thermolytic processes of respiration,cutaneous circulation and sweating in the nearly starved animals. Thus,heat tolerance figures from under-nourished animals may be falsely low.

A particular disorder interfering with the power of temperature regulation is that of chronic panting which has been observed in India as a sequel to foot and mouth disease (Minett, 1948). The state of the animal is characterized by a high respiratory activity and a long, rough hair coat. It was concluded that there was a more or less permanent failure of temperature regulation due to defective functioning of the endocrine glands. It hardly needs stressing that the performance of such animals in a heat tolerance test will give a grossly distorted picture. Less obvious cases of disease, such as the early phase of an infection,however, may escape attention thus leading to wrong heat tolerance results.

EMOTIONAL EXCITEMENT

Testing for heat tolerance involves a certain amount of handling of the animals.If not used to it, animals may work themselves into a state of excitement,as evidenced by an increased cardio-respiratory activity and in more severe cases even by a rise in body temperature, resulting in a reduction in heat tolerance. Moreover, such changes are unpredictable in their intensity and therefore adjustment for them is not easy.Excitement may be overcome with tranquilizing drugs, but these have side effects on physiological functions involved in thermoregulation which makes them unsuitable for use in heat tolerance tests.It is therefore important to reduce excitement to a minimum by allowing the animal to get used to the environment in which the test takes place, to the person who is conducting the test and to the procedure itself.Otherwise the innately excitable,brisk animal, as compared to the tranquil, docile animal, will be underrated in its capacity for tolerating heat.

S U M M A R Y   A N D   C O N C L U S I O N S

Heat tolerance is a complex phenomenon, since it involves the impact of one complex system - the thermal environment - on another complex system - the animal's body. The numerical evaluation of an animal's heat tolerance in form of a test cannot take into consideration all climatic elements and all animal characters. A selection of the most important and most suitable factors has to be made.

Many climatic environments are adequately characterised by temperature and humidity. Some, however, require the inclusion of solar radiation.The heat load imposed on an animal in a heat tolerance test should be large enough to evoke a pronounced response but not so large as to cause damage.

Various morphological features such as texture and colour of the hair coat are directly or indirectly related to heat tolerance. Although they cannot be used as criteria in a heat tolerance test proper, they have prognostic value, in that they allow a breeder to make a certain prediction of a young animal's future heat tolerance,which is of great practical importance.

Among the various body functions, body temperature is the best single criterion of an animal's heat tolerance.Representing the resultant of all heat gain and heat loss processes of the body it is physiologically meaningful; furthermore,it is relatively stable in a temperate environment, it responds readily and in a repeatable way to heat stress and it is easily and accurately measured.Estimating heat tolerance from respiratory activity or cutaneous evaporation alone is less satisfactory for reasons discussed.

Live weight gain in hot conditions may be a useful indicator of an animal's heat tolerance, while milk production seems to be less suitable in this respect.The question whether or not the concept of heat tolerance based on various thermoregulatory reactions of an animal should be abandoned altogether and replaced by production records, is touched upon.

From a description of various methods for assessing heat tolerance,it is concluded that none of them is entirely satisfactory and that in view of the necessity to increase animal production in hot countries there is a definite need for an improved method.

An animal's inherent heat tolerance - the determination of which is the aim of a heat tolerance test - is modified by a number of conditions and factors which will or may vary during an animal's individual life. The most important of these are age,nutrition,activity, reproduction, level of production, acclimatization, management, state of health and emotional balance. It is important to know how and to what extent these factors influence heat tolerance; they then may be eliminated, standardized or adjusted for.

Considering the problem of heat tolerance of cattle in its widest context, a general four-step procedure may be envisaged:

(1) Young animals are selected for heat tolerance on the basis of structural characters, for which correlations with suitable thermoregulatory responses has previously been established. Various properties of the hair coat are, at present, the most promising characters to be used in this way.
(2) At an age not less than about half a year the animals so selected are subjected to a suitable heat treatment in order to allow their temperature regulating mechanisms to attain maximal efficiency, i.e. to become fully acclimatized.
(3) These preselected and pretreated animals are then subjected to one or several suitable heat tolerance tests which include,as stress producing climatic factors,environmental temperature, air humidity and radiation in suitable intensities, and in which body temperature occupies a central position among the physiological variables measured.
(4) Once the animals selected in this way have reached their productive stage and are living in or have been transferred to a warm environment, they are finally selected on the basis of their productive level.

For the adoption of such a procedure which would consider, in successive steps,several different animal characters,it would be valuable to have more specific information on the role played by selected body structures in thermoregulation and there is clearly a need for a well defined and accurate test for assessing an animal's inherent capacity for tolerating a hot environment.

ABSTRACT

Heat tolerance is a complex phenomenon. Its study involves three factors: the thermal environment, the animal body and a suitable scale for expressing numerically the effect of the thermal environment on the animal body.

Since each of the principal component elements of a thermal environment, temperature, humidity, solar radiation and wind, makes specific demands on thermoregulation, it is desirable in a heat tolerance test to consider all of them. The total heat load imposed on an animal should be large enough to evoke a pronounced response, but not so large as to cause damage.

Various morphological characters such as the texture and the colour of the hair coat may have prognostic value, in that they allow a certain prediction to be made of a young animal's future heat tolerance. This is of practical importance for the breeder. Among the many physiological variables body temperature is considered the best single criterion of heat tolerance. Productive performance as an indicator to heat tolerance seems to be more useful in beef cattle than in dairy cattle.

From a description of the various methods which have been used for assessing heat tolerance, it is concluded that none of them is entirely satisfactory and that there is a need for an improved method.

An animal's capacity for tolerating heat is influenced by a number of modifying factors the most important of which are age, nutrition, physical activity, reproduction, level of production, acclimatization, management, state of health and emotional balance. Unless these factors are taken into consideration, heat tolerance tests will give misleading results.

ABSTRAKT

Hitzetoleranz ist eine komplexe Grösse. Für ihr Studium müssen drei Faktoren berücksichtigt werden: die thermische Umwelt, der tierische Organismus und ein geeigneter Masstab, der die Einwirkung der thermischen Umwelt auf den tierischen Organismus zahlenmässig zum Ausdruck bringt.

Da jedes der vier Hauptelemente einer thermischen Umwelt, nämlich Temperatur, Feuchtigkeit, Sonnenstrahlung und Wind spezifische Anforderungen an die Temperaturregelung des Körpers stellt, ist es wünschenswert, dass alle diese Elemente in einem Hitzetoleranz Test Berücksichtigung finden. Die gesamte Wärmebelastung, der ein Tier in einem Hitzetoleranz Test ausgesetzt wird, soll grosz genug sein um deutliche Reaktionen hervorzurufen, aber nicht so grosz, dass das Tier Schaden nimmt.

Verschiedene morphologische Merkmale wie z.B. die Beschaffenheit des Haarkleides können prognostische Bedeutung besitzen; d.h. sie können eine gewisse Voraussage der zukünftigen Hitzetoleranz eines jungen Tieres gestatten. Dies ist für den Tierzüchter von praktischer Bedeutung. Unter den zahlreichen physiologischen Grössen, die zur Beurteilung der Hitzetoleranz herangezogen werden können, ist die Körpertemperatur das beste Einzelkriterium. Unter den Nutzleistungen scheint das Körperwachstum geeigneter zu sein als die Milchproduktion.

Aus einer Beschreibung der verschiedenen Methoden, die als Bewertungsmasstäbe für die Hitzetoleranz verwendet werden, wird gefolgert, dass keine dieser Methoden vollständig befriedigt. Eine geëignetere Methode muss entwickelt werden.

Die Fähigket eines Tieres Hitze zu ertragen wird durch eine Anzahl modifizierender Faktoren beeinflusst. Die wichtigsten sind: Alter, Ernährung, Körperbewegung, Geschlechtsfunktionen, Nutzleistung, Akklimatisation, Haltung, Gesundheitszustand und emotionelles Gleichgewicht. Werden diese Factoren in einem Hitzetoleranz Test nich berücksichtigt, so entstehen irreführende Resultate.

RÉSUMÉ

La tolérance à la chaleur est une notion complexe.Trois facteurs doivent être considérés dans son étude: le milieu thermique, l'organisme animal et une unité de mesure capable d'exprimer quantitativement l'influence du milieu thermique sur l'organisme animal.

Un test de tolérance à la chaleur devrait tenir compte des quatre facteurs principaux du milieu thermique: la température, l'humidité, le rayonnement solaire et le vent, car chacun d'eux influence spécifiquement les mécanismes de régulation thermique du corps.La quantité totale de chaleur fournie à un animal au cours d'un test doit être suffisante pour déclencher des réactions nettes sans causer de troubles pathologiques.

Divers caractères morphologiques, comme par exemple l'état du système pileux, peuvent fournir une indication sur la résistance future à la chaleur d'un jeune animal;ceci présente une utilité pratique pour l'éleveur. Parmi les nombreuses mesures physiologiques qui peuvent servir à l'appréciation d'un test de tolérance à la chaleur, la température corporelle est le meilleur critère. Parmi les fonctions physiologiques,l'augmentation du poids du corps semble un critère plus utile que la production de lait.

L'examen des différentes méthodes utilisées pour évaluer la tolérance à la chaleur montre qu'aucunes d'elles n'est tout à fait satisfaisante. Une méthode plus appropriée doit être créée.

La résistance à la chaleur d'un jeune animal est influencée par une quantité de facteurs. Les plus importants sont l'âge, la nutrition, les mouvements, les fonctions sexuelles, le travail utile, l'acclimatation, la posture, l'état de santé et l'équilibre affectif. Les résultats d'un test de résistance à la chaleur qui ne tiendrait pas compte de ces facteurs sont douteux.

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A Method to Estimate the Effect of Weather Changes on the Growing Rat

by

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INTRODUCTION

The daily weight increase of growing rats with an unlimited supply of food and water in rooms at a constant temperature varies with small changes in the humidity milieu (Weihe, Brezowsky, and Schwarzenbach, 1961). This observation can be used as a method for the estimation of the physiological effect of certain climates and aperiodic weather changes, or for the estimation of the biotropic conditions of a particular room or building.

Weather dependent weight fluctuations are revealed by correlating the daily weight increase of rats: a) in closed rooms at an artificially maintained constant temperature with the humidity milieu of the outside climate, and b) in open rooms with the temperature-humidity milieu of the outside climate. According to recent investigations aperiodic weight fluctuations of rats are more marked in open rooms than in closed rooms (Weihe and Brezowsky, in preparation).

METHOD

Healthy rats of one strain from litters of the same age up to 40 days are divided into experimental groups of at least 25 animals according to age and sex. The animals are kept in basins made of steel or other non-transparent, strong material, with slits in the front side for air ventilation and covered with perforated steel lids. There are 5 animals to one basin. Because of the high heat conductibility of steel, in open rooms the cages are insulated outside on three sides, e.g. with thick cardboard.
Pellets of a standard diet and water are supplied ad libitum. A layer of thin, dry spruce or pine shavings (dust free) approximately 2 cm deep is used for bedding and should be renewed every second day. The cages are put on shelves at a height of about 1 to 1.5m, at a distance of at least 1.5 m from the outside walls, if there are any. For the closed room the windows are either left uncovered or are darkened and an artificial day is established from 7 am to 8 p.m. by means of an automatic switch clock; for the open room one or more windows are removed to permit free air exchange. For weather and climate studies, outside walls and particularly open windows should be situated north. Open rooms should be protected from wind and draft. A thermohygrograph is placed in a suitable place near the cages.

The animals are weighed daily in the morning between 9 and 10 a.m. on a fully automatic scale (Mettler-system). At this time all the other work such as cleaning the cages, is done. Apart from this work the animals should not be disturbed or irritated by noise, change of the regular cleaning scheme, admission of inexperienced assistants or visitors, smoking, etc. Spilling of water should be avoided. If the method is to be exact all the environmental conditions except for the meteorological factors should be considered and standardized with the greatest care, in accordance with the requirements of the animals for comfort.

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(2) Medizin-Meteorologische Beratungsstelle, Deutscher Wetterdienst, Bad Tölz/Bavaria.

The weight recordings are made during the time interval in which the mean weight/group increases from approximately 60 gm to 300 gm in male and to about 250 gm in female rats. Male rats are to be preferred to female rats because the oestrus cycle of the latter interferes with the investigation. The first stage in evaluating the data is to draw the mean weight curve for the entire observation period and to divide it into periods of from 10 to a maximum of 15 days.The estimated point of inflexion of the S-shaped weight curve is the orientation point for the subdivision, since in this region the regression of the weight increase is almost a straight line.The 5 days below and above this point are taken as the first period.Further periods are marked off in the lower and upper regions of the curve. In the last,upper part of the curve which is linear the periods can be as long as 15 days. For each individual animal the regression of the weight increase for each period is calculated and is plotted with the weight/day on graph paper. Of all the animals in each group the actual weights/day above (positive deviation)and below(negative deviation) the regression lines are counted. If the distribution curve of the actual weights is the same as the mean of the individual regressions of the group, the sum of the positive or negative deviations of the weights is equal to 1/2 N.If the distribution curve lies above the mean of the individual regressions,i.e.it is negative,the weight increase is smaller on this particular day.The significance of this deviation is checked by means of the"sign-test" (Wissenschaftliche Tabellen, 1961).To facilitate the calculation of the regression and the test for significance a form has been designed by Schwarzenbach (1961).

The mean regression coefficient b/group and period can be taken as an expression of the effect of climate. For the evaluation of weather effects the number of positive weight deviations/day is correlated either with the changes in the humidity milieu (for closed rooms at constant temperature) or with the temperature-humidity milieu (for open rooms) derived from aperiodic weather changes.According to the Tölzer method(Brezowsky 1960a,b) the changes in the dry-bulb and wet-bulb temperatures are an essential part of the total meteorological events (total meteorological complex: "Akkord") and are representative of the simultaneous changes of many other meteorological elements. The extent and speed of the air exchange between outside and inside is calculated from the standard recordings of the local meteorological station and the recordings of the thermohygrograph in the room.

RESULTS OBTAINED WITH THIS METHOD

The method was used to investigate the biotropy of weather in different climates at two closely situated places of different altitude: a) Bern, 540 m.a.s.l. and b)Jungfraujoch, 3,450 m.a.s.l., 50 km apart. One group of 25 male and one group of 25 female rats were kept at each place in laboratories at an artificially maintained constant temperature of 20-21^{o}C with an artificial day from 7 a.m. to 8 p.m.The rats were 40 days old at the beginning of the experiment and were investigated daily for 110 days (Weihe,Brezowsky, and Schwarzenbach, 1961).

Fig. 1 shows an example of the number of positive weight deviations/day correlated with the humidity milieu (dry-bulb and wet-bulb temperatures)derived from the weather events passing over the investigation places. On days with increasing humidity the majority of the weights were below, and on days with decreasing humidity above the mean individual weight increase.The results of this correlation were highly significant for the males and less significant for the females (Fig. 2).
The deviation of the weight distribution/day from the mean weight increase/period was more frequent and more extreme at high altitude with more extreme weather and more marked air exchange inside-outside than at ground level.From the few data available in the class $> 1.5\ \Delta$ F it is probable that there is a dose-response relationship (Fig.3) between humidity and weight deviation.

DISCUSSION

To interpret the weather dependent deviation of the weight distribution/day from the mean weight increase/period the following hypothesis was suggested. With an increase of humidity at a constant temperature the heat loss from the animal is impeded. The resulting heat congestion could lead to loss of weight because the resting metabolism is increased and/or the food intake is reduced by the animal to keep the heat production during the digestive phase low (Brobeck, 1960). The smaller weight gain on days with high humidity is compensated by the greater gain on days with low humidity. This problem is now being investigated in detail. The hypothesis that the heat regulatory mechanism is involved seems to be sustained by the different responsiveness of female and male rats.The poorer responsiveness of female rats is most probably due to the endogenous thermoregulatory mechanism during the oestrus cycle (Brobeck,Wheatland, and Strominger,1947),which is little influenced by climate changes of moderate intensity.

Because the investigations have been performed in rooms protected from sun, wind, and draft, sun radiation and air movement have not been considered yet.Air movement certainly plays an important role in these studies.

In our opinion the investigation of the biotropy of climate and weather can only be studied satisfactorily on laboratory animals because only for these can all environmental factors besides the meteorological ones be standardized and detailed physiological studies be performed.

Any deviation from the diurnal rhythm of the normal weight curve of a healthy animal with an unlimited food supply is induced by the environment,and is the expression of specific adaptive reactions in the body metabolism. For the investigation of the effect of weather on the body under standard conditions,the body weight can serve as a valuable indicator in deciding on detailed physiological studies.

Thus the method of correlating the daily weight increase of rats with the temperature-humidity milieu is useful in biometeorological research for two reasons:

1) It offers the possibility of investigating the effect of climate and weather on small laboratory animals.
2) It makes comparative observations in very different climates possible with genetically similar animals under standardized conditions.

Comparative investigations under standard conditions provide not only information about the biotropy of aperiodic weather events in different climates but also information about the effect of various climates,about the dose-response relationship between weather changes and body weight, the tolerance threshold,the adaptability of the animals and the time required for adaptation and acclimatization. Climate chambers are not suitable for the long observation periods necessary.

The conditions under which the measurements are carried out must be based on a uniform program for standardization worked out between the Institutes concerned.

SUMMARY

A method is described by which the effect of weather changes on growing rats can be estimated. The number of weight deviations per day of the mean individual weight increase per period of groups of male and female rats, kept in closed or open rooms is correlated with the temperature-humidity milieu of the outside climate.Results obtained with the method are mentioned.

ZUSAMMENFASSUNG

Es wird eine Methode beschrieben mit der die Wirkung von aperiodischen Wetteränderungen auf Ratten bestimmt werden kann. Die Anzahl Gewichts Abweichungen pro Tag vom mittleren individuellen Gewichtsanstieg pro Periode in einer Gruppe männlicher oder weiblicher Tiere, die in offenen oder geschlossenen Räumen gehalten werden, wird mit dem Temperatur-Feuchte Milieu des Aussenklimas korreliert. Ergebnisse, die bisher mit der Methode gewonnen wurden, werden berichtet.

RÉSUMÉ

Une méthode permettant d'évaluer l'effet de changements de temps apériodiques sur le rat est décrite. Dans un groupe d'animaux mâles ou femelles gardés dans des espaces fermés ou ouverts, le nombre des déviations de poids, déterminé chaque jour à partir de la moyenne d'une période de croissance est mis en corrélation, avec le milieu température-humidité résultant du climat ambiant externe. Les résultats déjà obtenus à l'aide de cette méthode sont rapportés.

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WISSENSCHAFTLICHE TABELLEN, DOCUMENTA GEIGY (1961) J.R. Geigy A.G. 6. Auflg. Basel.

Fig. 1

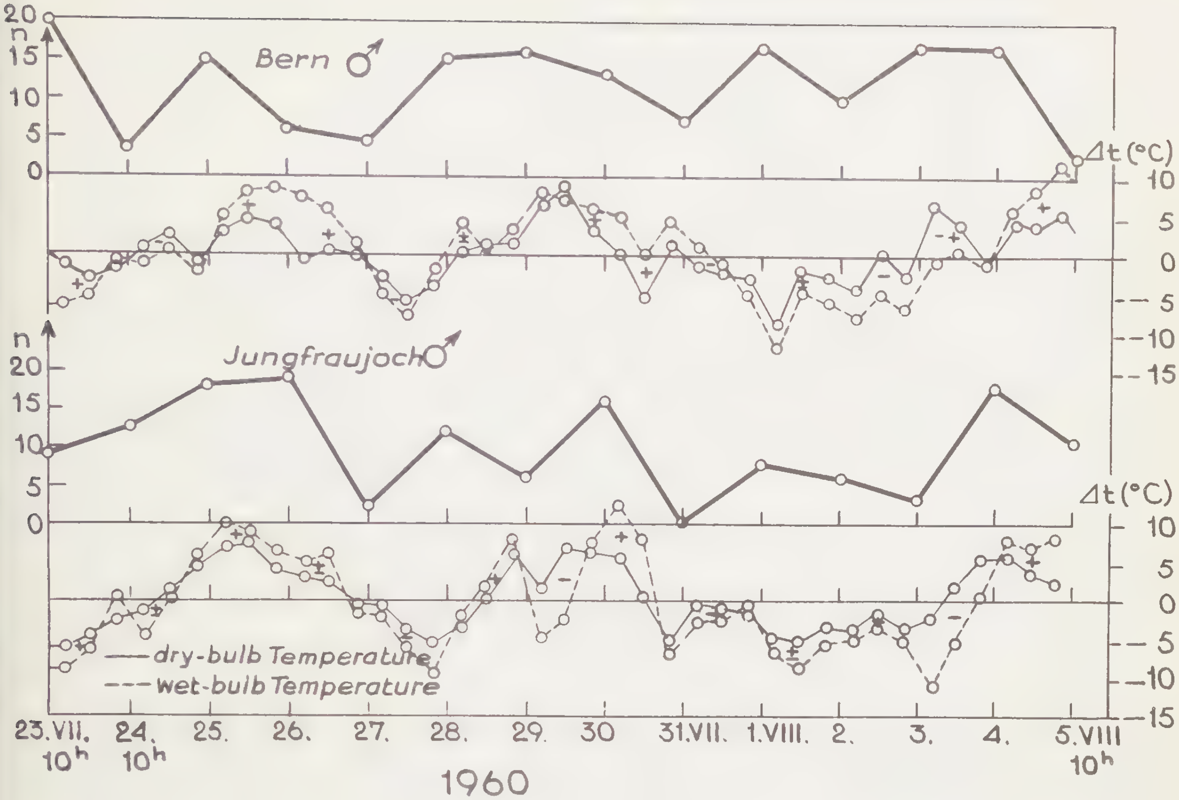

Fig. 1.:

Number of positive weight deviations/day from individual regressions/group at 10 a.m. during the period 23 July to 5 August 1960, and the simultaneous changes of dry-bulb and wet-bulb temperature. Wet-bulb temperature in double scale of dry-bulb temperature. Movement of dotted line upwards = increase in humidity, and downwards = decrease in humidity. (From Weihe, Brezowsky, and Schwarzenbach, 1961).

Fig. 2

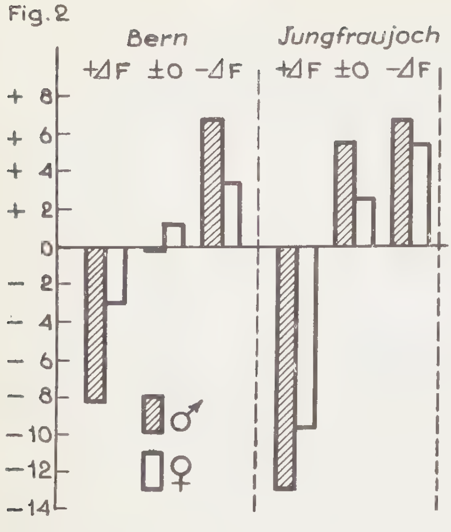

Fig. 2.:

Mean of number N of aperiodic weight deviations/day from indivi-
dual regressions/group in relation to aperiodic changes of humi-
dity $\triangle$ F of the outside climate.
(From Weihe, Brezowsky, and Schwarzenbach, 1961).

Fig. 3

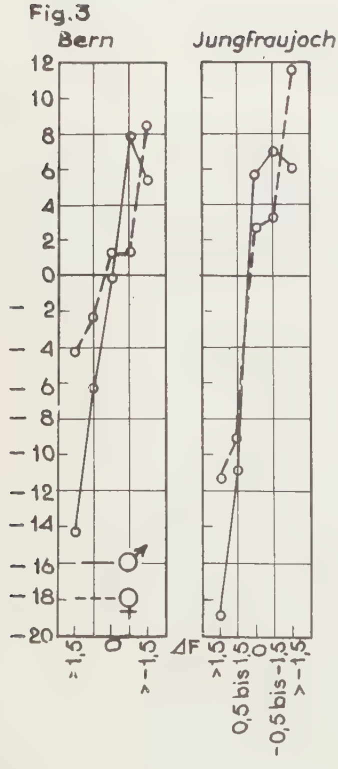

Fig. 3.:

Relationship between aperiodic weight deviations from individual
regressions/group (ordinate) and humidity ($\triangle$F, abscissa), shown
for different classes of $\triangle$ F.
(From Weihe, Brezowsky, and Schwarzenbach, 1961).

The Mechanism of Hidromeiosis

by

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The major homeothermic defensive mechanism possessed by man exposed to hot atmospheres is the production of sweat for evaporative cooling. Characteristically, when the eccrine sweat gland must produce copious volumes of sweat for several hours, the rate of sweating progressively declines from a high value which is usually achieved after 1 – 2 hours of exposure to a low value which is reached after 4 – 6 hours. This progressive decline of the rate of thermally induced sweating has been identified as hidromeiosis. (a comparable condition may be induced locally by repeated intradermal injections of such sudorific agents as acetylcholine or acetyl-β-methylcholine). The rate of decline of sweating is greater in humid heat than in dry heat. The degree of depression is linearly related to the initial outburst of sweating, suggesting that the rate of sweating must exceed a certain value before hidromeiosis will develop. The depression cannot be considered adaptive, for frequently the rectal temperature rises rapidly while the rate of sweating is declining. Duration of exposure to heat rather than intensity of physical work is a significant factor. Dehydration may accelerate the onset of hidromeiosis. This depression of sweating can be produced with greater regularity in the climatic chamber than under natural conditions.

Hidromeiosis is an important condition to elucidate, for understanding its process will augment knowledge of how the eccrine sweat gland produces sweat and clarify the basis for failure of sweating in the absence of poral closure, e.g. the anhidrosis of heat hyperpyrexia. The central problem of hidromeiosis is its mechanism.

The eccrine sweat gland is reflexly stimulated by secretary impulses carried over cholinergic sympathetic nerves. The reflex may be initiated by the response of thermal receptors in the skin acting on the hypothalamic center for heat dissipation or by warmed blood acting on this same hypothalamic center. Thus hidromeiosis may involve functional disturbances arising centrally in the hypothalamus or peripherally. In the latter case, the dysfunction may be in the response of dermal receptor, at the neuroglandular junction, or in the eccrine sweat gland itself. The facts support the view that hidromeiosis arises from pathophysiological alterations in the skin rather than in the hypothalamus.

W.S.S. Ladell (1957) has proposed that the progressive depression of sweating is the physiological consequence of an elevated rectal temperature. Three facts convincingly refute this hypothesis. First, anhidrosis and severe hypohidrosis have been observed among men with only slightly elevated rectal temperatures (Bannister, 1959; Sargent and Johnson, 1960). Second, if the arm of a subject exposed to a hot dry atmosphere is enclosed in a rubber glove, the rate of sweating and the number of active sweat glands within this vapor barrier rapidly decline within two to three hours; when the glove is removed, the rate of sweating and the number of active glands rapidly rises (Collins, 1960). Third, when a subject marches on a treadmill (M.R. approximately 190 Cal/m2/hr) for six hours in moist

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heat (32.7°C, D. B.; 30.5° W. B.), there is a progressive decline of sweating; subsequently, when the subject is abruptly transferred to dry heat (41.6°C, D. B.; 27° W. B.) of the same corrected effective temperature (30.6°C) there is a rapid recovery of the rate of sweating during the next two hours even though the rectal temperature continues to rise (table 1). When, on the other hand, the subject is not transferred to dry heat but continues to march in moist heat, the rate of sweating continues to fall (table 1).

These facts suggest that hidromeiosis originates from a rapidly reversible disturbance localized in the skin. Several conditions must be fulfilled to initiate hidromeiosis: (1) the eccrine sweat glands must be active; (2) the skin temperature must be elevated, and (3) the skin must be wetted (Collins, 1960; Hertig, Riedsel, and Belding, 1961). When the skin is 100 per cent wetted with such hypotonic solutions as water or weak solutions of sodium chloride, water penetrates the skin and collects within its layers (Buettner, 1959). When, however, the skin is wetted with hypertonic saline, particularly 10 - 15 per cent NaCl, water moves out of the skin (Buettner, 1959), and under these conditions hidromeiosis does not develop (Hertig, Riedsel, and Belding, 1961).

Presumably then the accumulation of water within the skin which is wetted is a necessary precursor of hidromeiosis. How this water impedes the activity of the sweat gland has not been established. Four hypotheses may be offered. First, the accumulated water dilutes the environment of the receptor for the sweating reflex and consequently depresses the irritability of this organ. Second, the transmission of the nerve impulse at the neuroglandular junction may be impaired. Third, the reactivity of the sweat gland may be depressed. Fourth, all portions of the reflex may be reactive and the gland may be unimpaired yet the sweat cannot be discharged because the hydrophilic keratin ring has swollen and occluded the duct. Hertig, Riedsel, and Belding (1961) have recently suggested the first explanation but their report contains no observations supporting the hypothesis. Randall and Peiss (1957) favour the fourth alternative and their observations on the hand and foot where the keratin layer is thick are most suggestive. Preliminary experiments from the author's laboratory indicate that during hidromeiosis the sweat gland, rather than being stimulated by intracutaneous injection of acetyl-β-methylcholine (20 γg/0.1 ml of saline), is actually depressed. This fact does not support the proposal of Hertig and coworkers. It does, however, suggest that the sweat gland itself may also be involved in the process. An observation which supports this view derives from the linear relation between the degree of depression and the magnitude of the maximal sweat rate achieved by a subject. For the unacclimatized male, there is no hidromeiosis if the rate of sweating does not exceed some 400 gm/hr (Sargent, Pessa, and Brown, unpublished). For the acclimatized male there is no hidromeiosis if the rate of sweating does not exceed 700 gm/hr. The susceptibility of the acclimatized sweat gland to the conditioning influences of a wetted skin differs from that of the unacclimatized sweat gland by an order of magnitude of two. This difference must be accounted for in any explanation of hidromeiosis.

The rate of sweating is the consequence of the output of sweat per individual sweat gland and the number of active sweat glands per unit area of skin. Hidromeiosis among four subjects studied in the author's laboratory was due to both processes but there were marked and puzzling individual differences. For one man the depression of sweating seemed predominately due to reduction of the sweat rate of the individual glands; for another reduction of the number of active glands was the principal process. Similar observations have been made in studies of the hidromeiosis provoked by repeated injections of acetyl-β-methylcholine (Sargent and Dobson, 1961). These individually different responses to identical thermal conditions may ultimately be clarified by histochemical studies of sweat glands in biopsies taken during the development of hidromeiosis.

SUMMARY

The problem of hidromeiosis is its mechanism.Hidromeiosis is a rapidly reversible pro-
ess and an active sweat gland and a wetted skin are necessary conditions for its deve-
opment. The threshold for hidromeiosis is lower for unacclimatized than acclimatized ma-
es. The facts suggest that accumulation of water in the skin and depression of the ec-
rine sweat gland may be involved in the explanation of the condition.Histochemical stu-
lies of the sweat glands during the development of hidromeiosis should elucidate curious
individual differences in the manner in which the depression of sweating develops and the
role of the sweat gland in the process.

ZUSAMMENFASSUNG

Der Wirkungsmechanismus der Hidromiosis (progressiver Abfall der Schweissmenge bei ho-
ner Umgebungstemperatur) ist noch nicht aufgeklärt. Aktive Schweissdrüsen und nasse Haut
sind für die Auslösung der Hidromiosis notwendig; der Vorgang is leicht reversibel. Der
Hidromiosis-Schwellenwert ist bei nicht-akklimatisierten Männern niedriger als bei akkli-
matisierten. Diese Tatsachen führen zu der Annahme,dass die Ansammlung von Wasser in der
Haut und die Unterdrückung der Sekretion der Schweissdrüsen für die Erklärung des Vor-
gangs eine Rolle spielen können. Durch histochemische Untersuchungen der Schweissdrüsen
während Hidromiosis sollte es möglich sein die sonderbaren individuellen Unterschiede in
der Art wie sich der Abfall des Schwitzens entwickelt und die Rolle der Schweissdrüsen
dabei aufzuklären.

RÉSUMÉ

Le mécanisme de l'hidromiose (diminution progressive de la quantité de sueur lors de
températures externes éleyées) n'est pas encore éclairci.Des glandes sudoripares actives
et une peau humide sont nécessaires pour que l'hidromiose se produise; le processus est
aisément réversible.Le senil de température de l'hidromiose est plus bas pour des hommes
non acclimatés. Les faits font supposer que l'accumulation d'eau dans la peau et la gène
de la sécrétion des glandes sudoripares peuvent jouer un rôle dans l'explication du pro-
cessus. L'examen histochimique des glandes sudoripares pendant l'hidromiose devrait ex-
pliquer les remarquables différences individuelles dans l'apparition de la diminution de
sudation et le rôle des glandes sudoripares.

TABLE 1

Unacclimated young male marched at 3.5 m.p.h. four times in moist heat for six hours. On three occasions he was abruptly transferred to dry heat for two additional hours; on one occasion he spent all eight hours in moist heat. Water balance was maintained by constantly sipping water equal in volume to sweat loss. Mean results are shown.

Measurement	Hours in moist heat								Dry heat	
	1	2	3	4	5	6	7	8	7	8
Sweat Rate, gm/hr	444	598	592	541	496	476	441	445	720	791
Rectal Temperature, ^{o}C	36.9	37.4	37.7	37.9	38.2	38.6	38.5	38.9	39.0	39.4
Skin Temperature, ^{o}C(Medial Thigh)	35,2	35.4	35.3	35.7	35.9	36.1	35.6	35.8	37.3	37.8

R E F E R E N C E S

This manuscript is based on a more extensive review of the literature entitled "Depression of Sweating in Man": so-called "sweat gland fatigue" which will be published in ADVANCES IN THE BIOLOGY OF SKIN (W. Montagna, ed.) Pergamon Press, London, Volume 3, 1961, in press. This review should be consulted for references not specifically cited in the present statement of the problem of hidromeiosis.

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Conference Report

First International Conference on Ionization of the Air

Sponsored by the American Institute of Medical Climatology (A.I.M.C.)
at the Franklin Institute of Philadelphia,

16-17 October 1961

by

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On Monday, 16 October, 1961, the meeting was opened with an address of welcome by the president of the AIMC, Dr. George M.Piersol, in the large auditorium of the Franklin Institute. After a short delineation of the "Aims of the Conference" by the Co-Chairman of the Conference, Franklin W. Edwards, the General Chairman, Dr. Clarence W. Hansell, conveyed greetings from Prof. L.L. Vasiliev of the Pavlov Institute of Physiology of the Academy of Sciences of the USSR.

The first technical session came to a good start with a clear and thorough introduction to aeroionization by C.W. Hansell, R.C.A., Princeton. The physics of air ions, their interaction, recombination and decay, formation of condensation nuclei, aerosols and measuring techniques were discussed by Rudolph Nagy, Westinghouse Corporation, Bloomfield, N.J.; J.C. Beckett, Palo Alto Engineering Company, Palo Alto, California; K.E. Schaefer, U.S. Submarine Base, New London, Connecticut; L.H. Ruhnke, U.S. Army Signal Research and Development Laboratory, Fort Monmouth, N.J.; P. Kranz and T.A. Rich,General Electric Company, Bridgeport, Connecticut and Schenectady, N.Y., and K.T. Whitby and A.R. McFarland, University of Minnesota, Minneapolis, Minn.

The paper by Dr. Reinhards Siksna, University of Uppsala,Sweden,dealt with experimental approaches in work with artificially generated,unipolar air ions from radio-active sources. An intricate analysis of the electric charges in automobile exhaust gases was given by R.W. Burhans of the Standard Oil Co. of Ohio in co-operation with J.V. Derau of the Philco Corp. A.G. Corrado, W.E. Cawley and R.G. Clark,Environmental Research Associates, Richland, Wash., reported on natural ion densities in Richland, Washington. F.K. Davis, Drexel Institute of Technology and F.P. Speicher, Philco Corp., correlated data for 12 months on outdoor ion concentrations in Philadelphia with various atmospheric conditions. The authors observed that the mean negative ion level exceeded the mean positive ion level during weather patterns usually associated with a feeling of well being. During the second session, chaired by F.P. Speicher, J.L. Worden of St. Bonaventure University summarized his findings on experimental animals and cell cultures exposed to unipolarly ionized air. His conclusions are of basic importance to clinical work with ionized air. Prof. Dr. A.A. Minkh, Moscow, Corresponding Member of the USSR Academy of Medical Sciences, found that a group of athletes treated daily for 15 minutes with negatively polarized air has shown a significant improvement of their performance as compared with controls. Negatively ionized air also reduced the need for higher amounts of water soluble vitamins during strenuous sport exercises.

Christian Froger, Societé Rhovyl, Paris, France,described the effects of negative friction electricity produced by fabrics from polyvinyl chloride fibres when in contact with human skin. The negatively charged garments seem to have an analgesic effect in selected cases of rheumatism, arthritis and neuralgia, Other artificial fibres, wool and silk ge-

nerate positive friction electricity which is therapeutically inert. Christian Bach of Randers, Denmark, described a high voltage ion generator which uses selected plants for emission of negative ions. It is being employed extensively and with good results in cases of asthma. It may be interesting to note that the ion levels produced by his generator are relatively low. The German method of electro-aerosol therapy(charged liquid aerosols) of bronchial asthma, whooping cough and chronic bronchitis was dealt with in great detail by A.P. Wehner, of Dallas, Texas. Many electro-aerosol inhalatoria exist in Western Europe and in the Soviet Union.

A.J. Levine; M. Finkel; J. Handler and Wm. I. Fishbein of Chicago presented their findings with negative ions in a variety of disorders.Seventy-five patients in the age group from 16 to 68 years were treated.The authors concluded that negative air ion therapy can be recommended for symptomatic relief of bronchial asthma, bronchitis and allergic rhinitis.

Substituting for the author, A.P. Krueger of the University of California,Berkeley,Calif., Cpt. J.L. Kinsey, MC, USN, read a paper and showed a color film of the effects of ionized air on the trachea and the movement of the ciliae.

During the third session on Tuesday, 17 October,chaired by Frank C.J. McGurk,Villanova University, Villanova, Prof. Dr. M.Knoll, Technische Hochschule, Munich, reported on the work with ionized air in his Department.He described a small battery operated ion counter and the set-up for reaction time test. J. Rheinstein,Lincoln Laboratories,MIT,summarized his extensive work on the influence of atmospheric ions on the reaction time and on the optical moment. Experimental controls was the topic selected by Allan H.Frey, G.E.Advanced Electronics Center, Cornell University, Ithaca, N.Y. Most significant results of a broad study of man's reaction to an ionized air environment were discussed by L.Slote of the College of Engineering, New York University, New York.

The last paper by I.H. Kornblueh, The Graduate School of Medicine University of Pennsylvania, Philadelphia,stressed the importance of continuous research on the clinical and psychological effects of unipolarly ionized air.He analyzed the possible health benefits from an addition of ionized air to central heating and air conditioning systems and underscored the potential value of battery operated ion generators in fallout shelters, Kornblueh appealed for a close co-operation of physicians and engineers in all phases of experimental medicine which lack adequate diagnostic or therapeutic instruments. An animated round table discussion terminated the second day of an instructive and successful meeting attended by over 200 persons from this hemisphere and Europe.

On Monday evening a splendid dinner in the Franklin Hall of the Institute assembled all participants. After an Invocation by the Very Reverend James A. Donnellon, O.S.A., Vice President of the American Institute of Medical Climatology and former president of Villanova University, the master of ceremonies, Dr. George Morris Piersol introduced the speaker, Dr. W.F.G. Swann, Director Emeritus, Bartol Research Foundation of the Franklin Institute. "Atmospheric Electricity and Atmospheric Ionization" was the theme of the address of Dr. Swann. His oratorial skill and the profound knowledge of the selected topic left the audience in a state of deep and grateful admiration.

Credit for the tireless attention to all details preceding and during the Conference goes to F.P. Speicher, Director, AIMC and L.A. Staebler, Philco Corp.

All papers presented at the First International Conference on Ionization of the Air will be published in the Proceedings of the Conference in February 1962. Orders for the Proceedings should be addressed to The American Institute of Medical Climatology, 1618 Allengrove Street, Philadelphia 24, Pennsylvania.

Announcement
Symposium on the Methodology of Plant Eco-Physiology

Organized by the Botanical Institute
of the University of Montpellier, France,
from 7-12 April 1962

An international symposium will be held on the "Methodology of Plant Eco-Physiology". The symposium will be devoted to measuring techniques employed in research on plant-environment relationships under arid and semi-arid conditions.

The authors will be allotted 25 minutes for each topic considered, followed by 10 minutes for a preliminary discussion. A general discussion will be held at the end of each session. A summary of each paper not exceeding 300 words should be sent by the author(s) to the organizer before 1 December 1961. The choice of the language in which the papers are to be given is left to the discretion of the author(s). Simultaneous interpretation, however, can be assured only from French to English and vice versa.

Address of the organizer: Dr.F.E.Eckhardt, Institut de Botanique, Montpellier, France.

INSTRUCTIONS TO CONTRIBUTORS

1) Papers should be written in English, French or German.

2) Papers should be typed on one side of the paper, quarto size, in double spacing, leaving top and left hand margin at least 2.5 cm (one inch) wide.

3) Papers should be headed by a title, the initials and name of the author(s) and an exact description of the post held and business address of the author(s). Dates should be in the form "5 February 1959".

4) Bibliographical references should be listed in alphabetical order at the end of the paper.

5) References to periodicals should include the following elements: name(s) and initial(s) of the author(s); year of publication (in parentheses); title of the paper; title of the periodical; volume number (arabic numerals); first and last page number. For periodicals the recognized abbreviations laid down in "World List of Scientific Periodicals 1900—'50" (London, 1952) should be used.
   Exemple: Cross, B. A. (1951): Suckling antidiuresis in rabbits, J. Physiol., 114: 447—448

6) References to books should include: name(s) and initial(s) of author(s); year of publication (in parentheses); exact title; name(s) of publisher, town of publication, page number (where pages are specifically cited).
   Example: Lee, D. H. K. (1957): Climate and economic development in the tropics, Harpers & Brothers Publ. Co., New York, p. 182
   When quoting consecutively from several papers published in the same periodical the word "ibid." may be used.

7) References should be cited in the text in parentheses by the name(s) of author(s) followed by the year of publication, e.g. "(Jones, 1961)"except when the authors name is part of the sentence, e.g. "Jones (1961) has shown that..." If there are more than three authors, it is in order to put "et al." after the first name (e.g. Smith et al., 1961).

8) Each table should be typed on a separate sheet of paper. Tables should be numbered consecutively in Arabic numerals, e.g. (Table 1, Table 2, etc.) and attached to the end of the text. Should a table not be an original, the exact reference should be quoted. Tables should be supplied with headings and kept as simple as possible and should be referred to in the text as "Table 2", etc.

9) Figures (including photographic prints, line drawings in black Indian ink on strong white or transparant paper, and maps) should be numbered consecutively in Arabic numerals (e.g. Fig. 1, etc.) and attached to the text after the tables. Graphs and diagrams should be large enough to permit reduction to a size of 10 x 10 cm (4 x 4 inches).
   In exceptional cases graphs or diagrams not complying to these rules can be redrawn for the author in the office of the Managing Editor at cost price.
   Photographs can be easily reproduced in off-set print but should be unmounted, glossy prints, permitting reduction to size 10 x 10 cm without affecting legibility.